ARCHIVES OF

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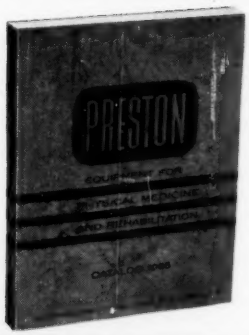

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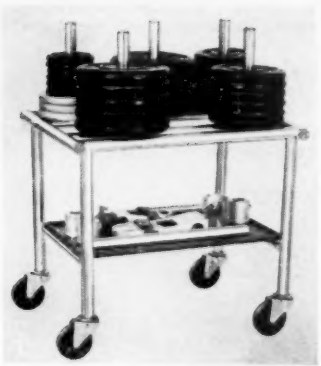

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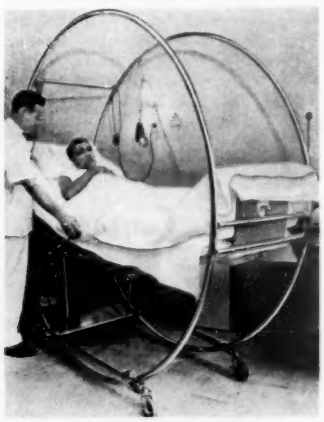

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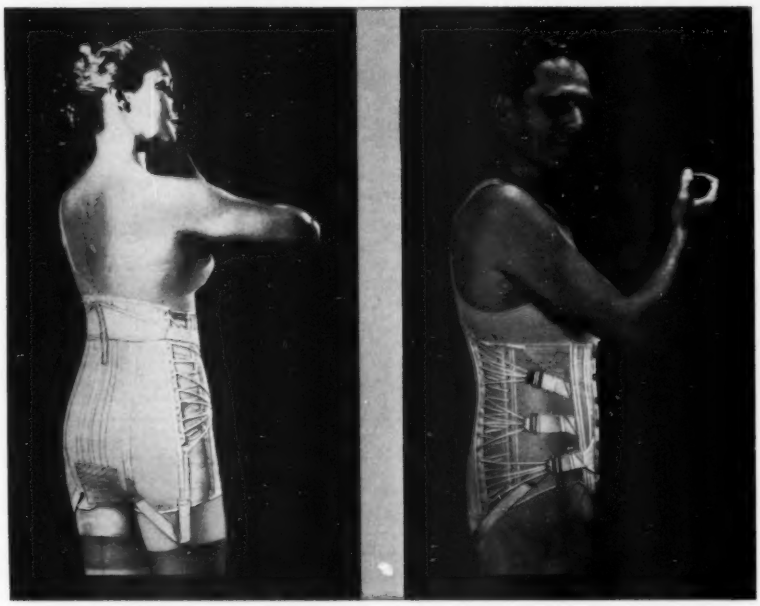

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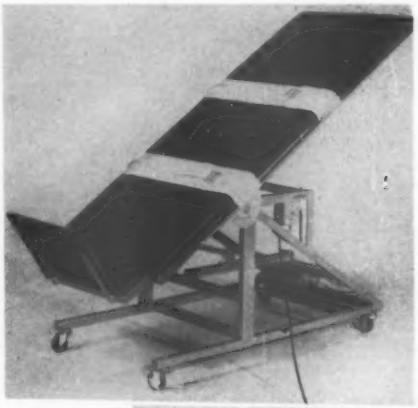

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FRANK H. KRUSEN, M.D., Executive Director, Elizabeth Kenny Institute, 1800 Chicago Ave., Minneapolis, Minn.

DR. PHILLIPE BAUWENS, St. Thomas' Hospital, London, England

MICHAEL KOSIAK, M.D., Department of Physical Medicine and Rehabilitation, University of Minnesota Medical School, Minneapolis, Minn.

DANIEL R. BOONE, Ph.D., Director Clinical Speech Pathology, Cleveland Hearing and Speech Center, 11206 Euclid Ave., Cleveland 6, Ohio

KARL H. HAASE, M.D., 7743 Yarmouth Ave., Reseda, Calif.

H. J. RALSTON, Ph.D., Biomechanics Laboratory, University of California, San Francisco Medical Center, San Francisco, Calif.

NICHOLAS PANIN, M.D., Physical Medicine and Rehabilitation Service, VA Hospital, Bronx 68, N. Y.

JAMES W. RAE, JR., M.D., Department of Physical Medicine and Rehabilitation, University of Michigan Medical School, 1313 E. Ann St., Ann Arbor, Mich.

EDWARD D. HENDERSON, M.D., Section of Orthopedic Surgery, Mayo Clinic, Rochester, Minn.

THOMAS E. TWITCHELL, M.D., Joseph P. Kennedy, Jr. Memorial Hospital, Brighton, Mass.

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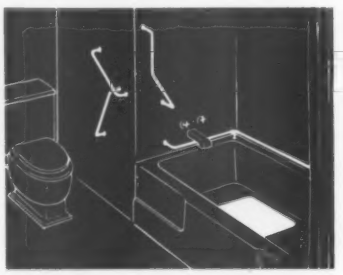

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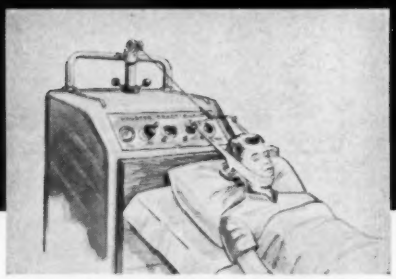

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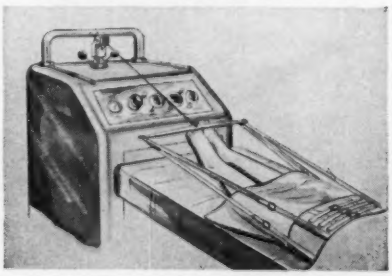

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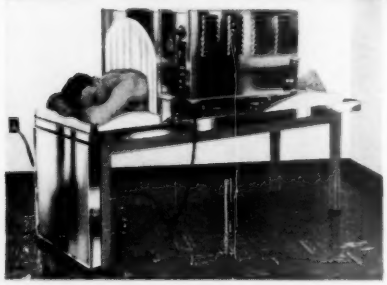

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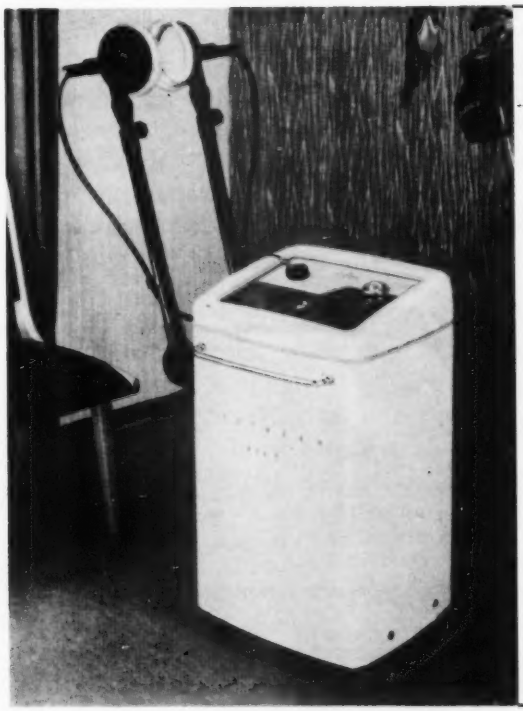

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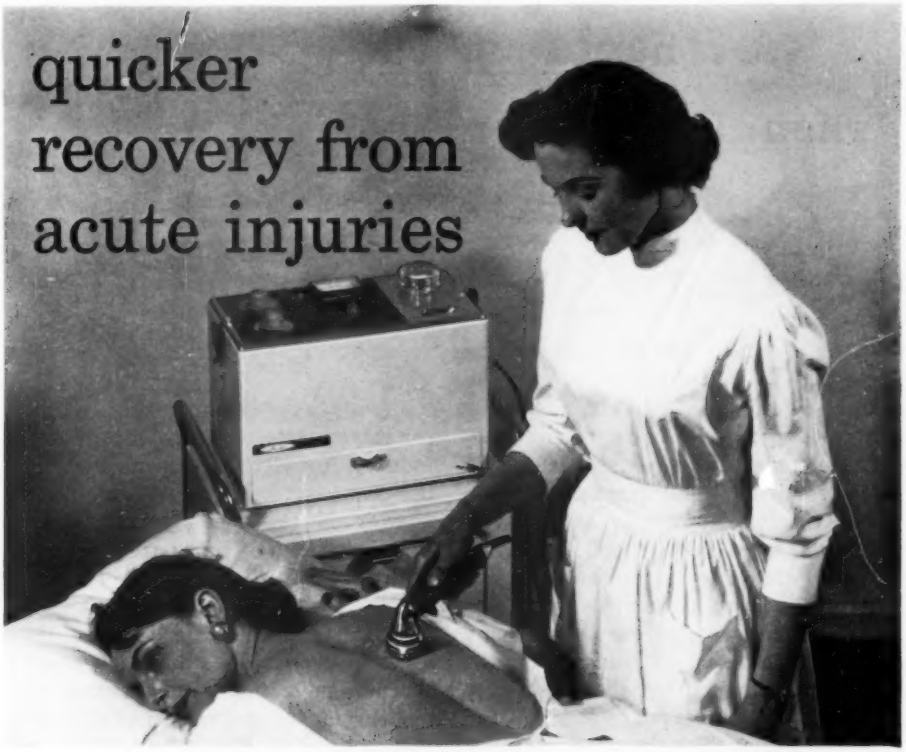

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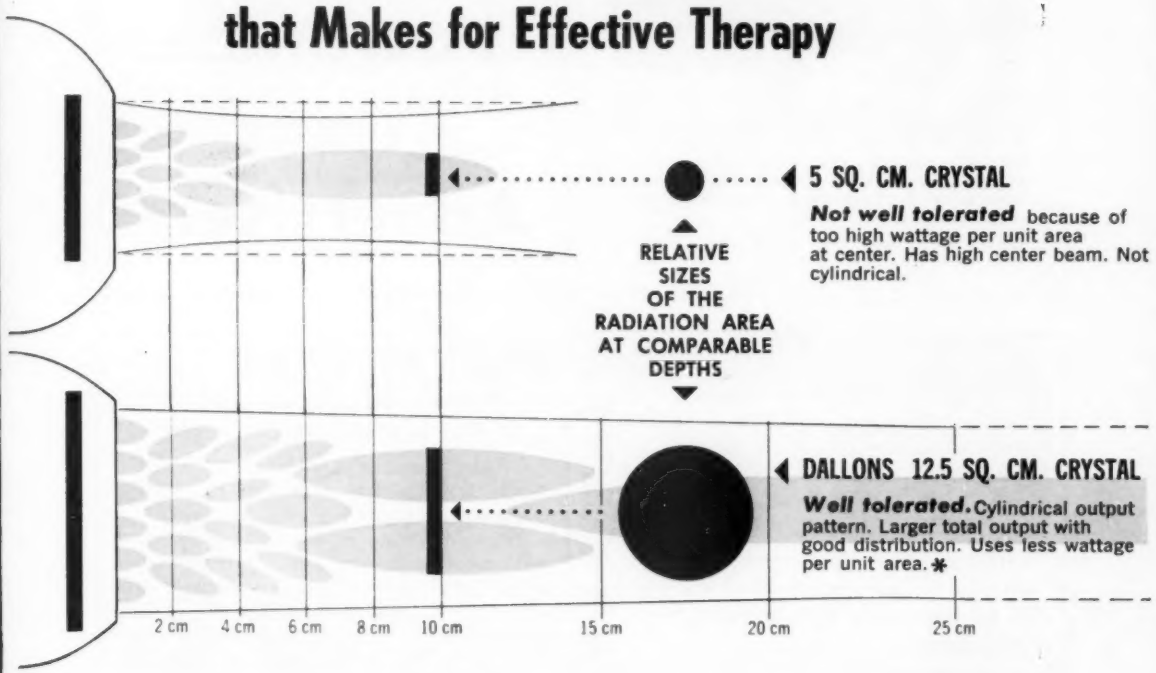
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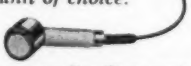

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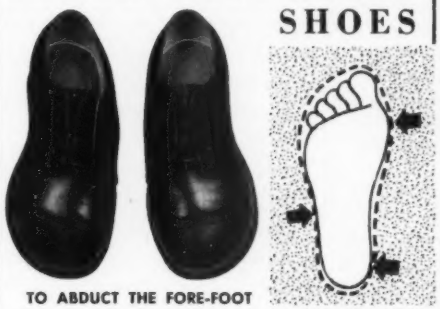

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The Art of Physical Medicine

Frank H. Krusen, M.D.
Rochester, Minn.

● The International Federation of Physical Medicine was organized in May, 1950; it held its first international Congress in London, England, in July, 1952, and its second in Copenhagen, Denmark, in August, 1956. A study, carried out for the Federation by a committee of Danish physicians, indicates world-wide interest in physical medicine as a specialty. The combination of Physical Medicine with rehabilitation has occurred in 11 of the 20 countries surveyed. Teaching of Physical Medicine to undergraduate medical students is provided in 14 of these 20 countries. At the first congress, the president, Lord Horder, stressed the importance of clinical practice, and at the second congress, the president, Dr. Clemmesen, emphasized scientific research, so now it seems advisable to discuss the "art" of Physical Medicine. Although progress in Physical Medicine depends on good clinical practice and research, these achievements will be relatively sterile unless physiatrists are adept in the art of Physical Medicine. The art of Physical Medicine leads us to have a deep concern for the humanitarian, social, and economic problems of our patients, and physiatrists are particularly concerned with the social and the community efforts in caring for the disabled. The specialists in this new medical discipline can provide the leadership for this mighty medical-sociologic movement in many countries. The art of Physical Medicine can lead us forward toward the goal devoutly sought by every man — health, peace and prosperity for all mankind.

The International Federation of Physical Medicine, which sponsors this 3rd International Congress of Physical Medicine, came into being on May 10, 1950, when a small group of physicians met in a committee room of the Royal Society of Medicine in London, England. Physicians representing seven countries — Australia, Denmark, Great Britain, The Netherlands, Sweden, Switzerland and the United States of America — had agreed to represent their countries in this Federation. At that time it was decided that the Federation should sponsor its first International Congress, to be held in London, England, in 1952. Consequently, on July 13, 1952, the first regular meeting of the delegates to the International Federation of Physical Medicine was held in a meeting hall at King's College in London, England. The delegates from the seven countries previously mentioned were joined by delegates from nine other countries: Argentina, Austria, Belgium, Canada, France, Germany, Israel, Norway and Spain. On the following day the 1st Congress under the auspices of the International Federation was convened in London, England. Actually, this was the seventh International Congress of Physical Medicine, because there had been six previous congresses held under various other auspices.

The 2nd International Congress of this Federation convened in Copenhagen, Denmark, in the Festival Hall of the University of Copenhagen on August 20, 1956. Today it is a privilege to welcome you to the 3rd Congress of the International Federation of Physical Medicine.

Headed by Dr. Jespersen, a committee of the Danish Association of Physical Medicine made, for our International Federation, a study of the education and training of personnel in physical medicine and rehabilitation. The result indicated that throughout the world keen interest is taken in physical medicine as a medical specialty. Already physical medicine has become an independent specialty in most of the member countries which have sent delegates to our Federation. In the countries in which this is not the case, it seems only a matter of time until the specialty will become independent. Therefore, we can look back with pride on the rapid advancement of our new medical discipline, and look forward with confidence to ever more rapid progress.

The frequent combination of physical medicine and rehabilitation, which was found to have taken place in 11 of the 20 countries studied by our Danish committee, indicates an important trend which must be given serious consideration. Although it is recognized that undergraduate training in physical medicine requires further expansion, it is encouraging indeed to find that already such teaching is provided in the medical schools of 14 of the 20 countries surveyed by the committee.

In his opening address to the 1st Congress held under the auspices of our International Federation in London, in

Professor of Physical Medicine and Rehabilitation, The Mayo Foundation, the Graduate School of the University of Minnesota; staff physician and senior consultant in Physical Medicine and Rehabilitation, the Mayo Clinic.

Presidential address at the Opening Ceremony of the 3rd International Congress of Physical Medicine, Washington, D. C., August 22, 1960.

July, 1952, Lord Tedder expressed the opinion that the greatest role of our medical specialty lies in the restoration of the person with physical deficits to the fullest possible fitness because, he said, "life was not merely to be alive but to be well." He was deeply interested in our branch of medical practice because physical medicine makes use of self-help so that the patient becomes a partner in his own treatment.[1]

Lord Horder, in his speech of welcome as president of this same First Congress of the International Federation, remarked that in recent years physical medicine has "expanded its scope and increased its prestige to a quite phenomenal degree." Physicians specializing in this branch of medicine not only save many lives but also accomplish the even more difficult feat of making these lives healthier and happier. This is "a much greater service to humanity than merely saving lives." Lord Horder stressed the care of the patient and repeated the maxim of the great clinician, Trousseau: "The patient, always the patient." He added that international congresses such as these "contribute to that seemingly 'far-off, divine event' when world fellowship shall replace world enmity, and peace, not war, shall be the order of the day."[2]

Dr. Svend Clemmesen, president of our 2nd Congress, held in Copenhagen in August, 1956, said in his address during the opening ceremony that "in the discipline of physical medicine, physics is the fundamental science." Then he indicated how various concepts derived from modern physics might be transferred, in a useful way, to physical medicine. He suggested that we might progress from the "either — or" and the "right — wrong" method of presenting our problems to the "both — and" method of presenting medical investigations, which is based on the theory of complementarity of the famed Danish physicist, Niels Bohr. "A phenomenon may have, and often has, more than two complementary aspects. . . . The use of the concept of complementarity has enabled us to overcome the difficulty of our habit of thinking in logical contrast."[3]

Since Lord Horder, the president of our 1st Congress, stressed the clinical features of our special field of medicine, and since Dr. Clemmesen, the president of our 2nd Congress, emphasized the scientific aspects of physical medicine, it seems appropriate today to discuss the art of medicine as it applies to our particular medical discipline.

There is a complementarity among the clinical, scientific, artistic and other aspects of physical medicine. Thus, even though this discussion will be concerned with the art of physical medicine, it should not be assumed that, of necessity, the artistic transcends in importance the clinical, scientific or other aspects of our special field of medical practice.

It is not inconsistent, therefore, to stress the clinical and scientific phases, as well as the art, of physical medicine. Although one may have said "the major responsibility of the physiatrist must always be in the clinical field. . . . the real future of physical medicine and rehabilitation lies in good clinical practice,"[4] and although one may also have said, "the real advances and improvements in caring for our disabled citizens will come through an ever expanding program of good, combined laboratory and clinical research,"[5] it should not be inferred from such statements that the art of physical medicine is not equally important. For, even though the future of physical medicine lies in good clinical practice, and although advances in our specialty will come chiefly from good research, these achievements will be relatively sterile unless we physiatrists are profoundly devoted to the practice of the *art* of physical medicine.

The art of physical medicine leads us far beyond the mere scientific management of a certain disease or disability. It inspires in us a deep concern for the humanitarian, or the social, or the economic problems of each individual. It moves us to a personal, rather than to an impersonal approach to the disabled person. Since disability not only affects, but is affected by, the emotional reactions of the patient, the specialist in

physical medicine must concern himself with the emotional problems, as well as with the physical problems of each of his patients. Not only must we physiatrists develop an ever-expanding program of sound research and good clinical practice, but we must also provide generously of our time, our sympathy and our understanding of each patient, for "the secret in the care *of* the patient is in caring *for* the patient."[6]

We practitioners of medicine who are concerned with the physical treatment and the rehabilitation of the handicapped must give ever more serious attention to the practice of medicine as a social science, as well as a physical science. Moreover, we must include in the care of our patients infinitely more than the mere establishment of a correct diagnosis, the provision of adequate medical and surgical care and the administration of physical treatment and measures to achieve emotional adjustment. Today the specialist in physical medicine must consider the physical, the psychologic, the social and the economic problems of every patient he sees.

During the first half of this century the medical profession made extraordinary progress in the management of acute illness, in the reduction of mortality and in the prolongation of life. Now we specialists in physical medicine must provide the leadership for achievement of similar progress in the management of chronic disability. The remarkable advances which have been made in the treatment of acute illness have produced for us a wholly new group of problems in relation to chronic illness. Too frequently in the past we physicians, because of our preoccupation with the enormously difficult problems encountered in the management of acute illness, and with the saving of lives, have tended to put off and to neglect our duties in the physical restoration of chronically ill and seriously disabled persons. The achievements of medicine in postponing death have created the necessity for the development of new approaches which will extend the physical treatment and rehabilitation of an ever-increasing number of chronically ill and seriously disabled persons. We have saved many chronically ill and seriously injured persons from death; but there can be worse things than death. Every physician must be a humanitarian: it is often more humane to save a chronically ill or seriously disabled person from years of dependency than it is to save his life.

In a book published in 1952, entitled *When Doctors Are Patients*,[7] several physicians described personal experiences with various serious diseases from which they themselves were suffering. It is a revelation to discover that almost every one of these physicians, as he recited the problems which he faced in dealing with his own serious illness, stressed not so much the physical as the psychologic and social aspects of his disease. This emphasized "in a peculiarly urgent and moving way how essential it is to treat the whole patient."[7]

A few years ago, in his report as president of the Rockefeller Foundation, Chester I. Bernard, in discussing medical care, commented: "The old idea that biophysics and biochemistry would eventually unravel all the problems of health and disease is less tenable today than was the case 40 or 50 years ago. There is a growing realization that interrelated social factors outside the physics and chemistry of the body also are involved. When research has accumulated and systematized the data into a scientific discipline, biosocial medicine may become an indispensable part of the school curriculum. We may expect medical schools then to introduce students to the practice of community medicine, with an emphasis on social diagnosis comparable to that on physical diagnosis."[8]

We physicians who specialize in the field of physical medicine are particularly concerned with the practice of medicine as it is related to the community; with the social and vocational aspects of medicine, as well as with the physical and psychologic aspects; and with the consideration of each patient as a whole.

There is presently in progress an amazing, vast, international humanitarian movement toward providing adequate physical rehabilitation for every handicapped person. We specialists in physical

medicine must provide the leadership in this mighty medicosociologic movement. This development which began in a small way after World War I burst forth with tremendous force after World War II. We physicians who are gathered here in Washington this week have provided leadership in many countries of the world in advancing the medical aspects of this great humanitarian movement.

We must remember always the necessity of practicing physical medicine as a social science, the importance of treating the whole man and the significance of considering always the physical, psychologic, social and vocational problems of each disabled or handicapped person who comes under our care.

Maximal restoration of disabled persons involves both the physical and the psychologic phases of medicine. The psyche and the soma are invariably interrelated. It is not possible to achieve maximal physical restoration without proper attention to the psychiatric aspects of the disability. If the handicapped person's mental, spiritual and motivational powers are directed toward his own recovery, he will make satisfactory progress. If not, no superlative physical medicine and no skillful rehabilitation procedures will be sufficient to achieve his complete recovery.

Productive employment of some sort, which will make a person useful and self-respecting, can be provided for nearly every disabled person no matter how seriously he is handicapped. Such employment must be procured for him. It is the responsibility of the specialist in physical medicine to administer the appropriate physical treatment for each patient who comes under his care from the moment the patient first becomes ill or is injured until such time as the patient is completely restored to the fullest possible physical, psychologic, social and vocational achievement of which he is capable. To restore to the fullest possible health and productivity the sick and disabled citizens of each nation represented here today is to establish a pattern for all the world to emulate.

The greatest hope of achieving the divine eventuality, sought by Lord Horder — of peace instead of war, of world fellowship instead of world enmity — lies in the development of international understanding and good will through mutual efforts of the physicians of all nations to provide for the health and welfare of all mankind. More than three centuries ago Descartes wrote, "If ever the human race is raised to its highest practical level intellectually, morally, and physically, the science of medicine will perform that service."[9]

We physicians gathered here this week from many lands representing many cultures, and having marked variations in our spiritual beliefs and in our political philosophies, must strive for international peace and good will by attempting to make our social achievements keep pace with our scientific achievements. "Medicine is coming of age as a social science in the service of society."[10] For it is medicine "with its age-old concern for the sick — the poor as well as the rich, the weak as well as the strong," which can best provide the inspired leadership throughout the world which will promote the welfare rather than the destruction of mankind.[11]

Supreme dedication to the *art* of physical medicine can lead us forward toward the goal devoutly sought by every man — health, peace and prosperity for all mankind. "For where there is love of man, there is also love of the art."[12]

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Information relative to securing reprints of this study may be had by checking the Reader Service column on page iv of this issue.

we meet . . .

in Cleveland . . .

in 1961 . . .

Electrodiagnosis Revisited: Tenth John Stanley Coulter Memorial Lecture

Philippe Bauwens, M.R.C.P.
London, England

● Electrodiagnosis can be regarded as one of the many facets of physical medicine since it is merely a specialized form of investigation into the function of muscle. Complete electrodiagnostic examination is a trilogy consisting of study of muscle behavior on stimulation, on electromyographic exploration and on electromyographic exploration during stimulation. In each case it is important to regard the structure examined and stimulated, not as an entity, but as a complex with a narrow range of characteristics in the normal state but a broader one in pathologic conditions. Pathology frequently is masked by normality and for this reason the plotting of intensity duration curves can be misleading. Electromyography at rest and on volition requires the patient's cooperation, but neither this nor consciousness is required when carried out during nerve or muscle stimulation. Moreover, it provides data for estimating the velocity of propagation of nerve impulses over different stretches of nerve trunk as well as for the rough evaluation of the prevalence of differential velocities along fibers. As excitability and velocity of conduction are both determined by the caliber of the axon, the results of these tests reflect the condition of the axon. It has been found expedient to coin the terms "axonostenosis" and "axonocachexia" to denote a local and a widespread reduction in girth of the axon, respectively. An important part of electromyography at rest, on volition and on stimulation is the search for muscle fibers which deviate from the normal and which provide clues of diagnostic value.

Physical Medicine is in the main concerned with disorders of the locomotor system which broadly speaking consists of the articulated bony skeleton and the muscles animating it.

It, therefore, calls for no apology if I include within the scope of physical medicine the art of electrodiagnosis, seeing that this is merely a highly specialized form of investigation into the function of the muscular component of the locomotor system, even though such examinations are frequently carried out to assist a neurologist reach a final conclusion.

Although the bony frame is far from being an inert structure, it hardly can be regarded as articulate in the sense that it is capable of expression. In contrast, muscles can — electrically speaking — be very vocal.

The language which normal and diseased muscles speak at rest, on volition, on chemical provocation or on electrical stimulation is in code form. The electromyographic facet of electrodiagnosis aims at intercepting, recording, deciphering and interpreting cryptograms of diagnostic significance.

One well may ask how so simple a structure as a muscle fiber can give rise to a sufficient number of cogent utterances to be of value? The answer, of course, is that although in isolation a muscle fiber is capable of producing only one type of electrical signal, together with others as a member of a motor unit or of a complex of motor units, it acquires a very wide vocabulary.

My proposition is that it is essential to approach a muscle to be examined, not as an anatomic entity, but as an integrated aggregate of muscle fibers organized into motor units.

It follows that the investigation should be conducted as a sort of census with a view to making a statistical survey. In electrodiagnosis ideally the aim would be to establish a rough estimate of the number of motor units of normal behavior in order to compare it with the number showing signs of degeneration, denervation, depletion, irritability or impairment of their remote control.

It cannot be too strongly emphasized that since representatives of the latter group rather than of the former are an expression of a pathologic situation, electrodiagnosis is to a large extent a search for deviants. At the same time it should be remembered that there are considerable variants among normal motor units. There is evidence that they differ in their muscle fiber content, their excitability, the order of their recruitment, the caliber of their motor neuron, their resistance to disease and even their more specialized function.

Although we learn much from the electrophysiologist, his aims and therefore his approach to a problem differ from ours. He frequently carries out his

Physician in Charge, Department of Physical Medicine and Director, School of Physiotherapy, St. Thomas' Hospital and Royal Marsden Hospital, London.

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experimental work on an isolated structure generally in order to satisfy his scientific curiosity or to enable him to verify a hypothesis or even to disprove someone else's.

In electrodiagnosis we make ample use of his teachings for the purpose of discovering the cause of muscle dysfunction as part of a clinical picture, but while transposing them into the key of human ailments, we remember that most of his work is carried out under the most artificial conditions, generally on normal animals and that most of the situations encountered as the result of disease are foreign to him because he cannot reproduce or study them in his laboratory.

On this memorable occasion, I do not propose to produce a rehash of what is already accepted as common grounds in electrodiagnosis. I should prefer to pay tribute to the memory of Coulter by making marginal notes with a personal bias.

To me, electrodiagnosis now appears as a triptych of which the methods relying on electrical stimulation and those involving simple electromyographic exploration are the side panels while the central panel combines both themes — that is electromyographic exploration during stimulation.

My comments on nerve and muscle testing by stimulation will be limited to a reminder that only too frequently does the normal behavior of intact muscle and nerve mask that of tell-tale deviants. This is particularly true in the case of technics depending on evaluations at threshold levels, as in the plotting of intensity duration curves. Unless changes are gross, such methods reveal little or nothing of situations that might prevail as the result of supra liminal and maximal stimulation.

For this reason I make use of these valuable methods solely to execute a rough sketch of the situation with a view to differentiating the normal and the near-normal from the frankly afflicted or to draw attention to some flagrant disparity.

Everyone now is well acquainted with the normal electromyographic picture displayed on the cathode ray tube during an examination: at rest, an undisturbed base line; on volition, progressing from minimal to maximal effort, a wave pattern consisting at first of a few low amplitude potentials growing in number and amplitude until finally the typical interference pattern prevails with, of course, the associated sounds from the loud speaker.

Nor do the accepted electrodiagnostic characteristics of a fully established myelopathy, neuropathy, myopathy, myotonia, myositis and myasthenia which are equally well known need reiterating. But since electrodiagnosis is of the greatest value where the disease exists in a mild form or is in the early stages and where the clinical picture is not clear cut, every effort should be made to see whether a more exhaustive electrodiagnostic examination possibly coupled with a muscle biopsy is not capable of yielding more conclusive evidence leading to a correct diagnosis under adverse conditions.

In this connection, it is of importance to remember that the small motor units which are recruited at the inception of volition appear to be the more vulnerable ones and consequently the ones more likely to show early departures from normality. In myopathies they are the ones that may reveal a deficiency of operative muscle fibers within the motor unit while in cord lesions they may appear to be merely incommunicado.

Examination of the pattern on full volition only may thus cause a valuable index to be missed. For the same reasons if a frequency analyzer is available it should be used both during minimal and maximal voluntary effort.

The search for deviants is also more rewarding in the early stages of volition. I mention this because in dystrophies, I have seen the typical myopathic pattern obtained at inception of volition literally eclipsed by the subsequent recruitment of more normal and presumably less vulnerable units on full volition.

Unlike electromyographic examination on volition, recording during nerve or muscle stimulation does not necessitate the patient's co-operation or even his consciousness. It eliminates those vagar-

ies due to the human element and therefore constitutes a very important objective aspect of electrodiagnosis. To invest it with its fullest value, it is essential to understand its mechanics and this demands a knowledge of the principles underlying nerve excitability, nerve conduction, transmission across the neuromuscular synapse, propagation of action potentials along muscle fibers and the technic of detection and recording of electrical phenomena for final analysis.

To this end, the nerve is stimulated at various levels where it is sufficiently superficial to be influenced by the electric field of the stimulating pulse and the resulting electrical phenomenon in the muscle picked up either with surface electrodes applied over the muscle or a needle electrode inserted into it.

If two channels are available, simultaneous pick up by means of surface and needle electrodes or pick up from two separate muscles can be achieved with advantages. Experience, however, shows that while surface electrodes readily pick up action potentials from normal or near-normal motor units, only needle electrodes can reveal the presence of short duration potentials, potentials with jagged wave form or where temporal dispersion is marked (fig. 1). Needle electrodes are the only ones which can profitably be used for probing a muscle in search of deviants.

The concept of an aggregate of excitable tissues must once more be borne in mind when the stimulus to a nerve is progressively increased, for a point will be reached at which the nerve fibers with the lowest thresholds will be excited and give rise, after an interval, to a response in the muscle fibers supplied by them. This latency, of course, is the sum of the times taken for conduction along the excited nerve fibers, for the synaptic transmission and for the propagation along the excited muscle fibers from the end plates to the pick-up electrode.

In the normal, because the range of thresholds is narrow, a further increase in stimulus-intensity soon produces the maximal response. Such a response may, however, be out of all proportion with

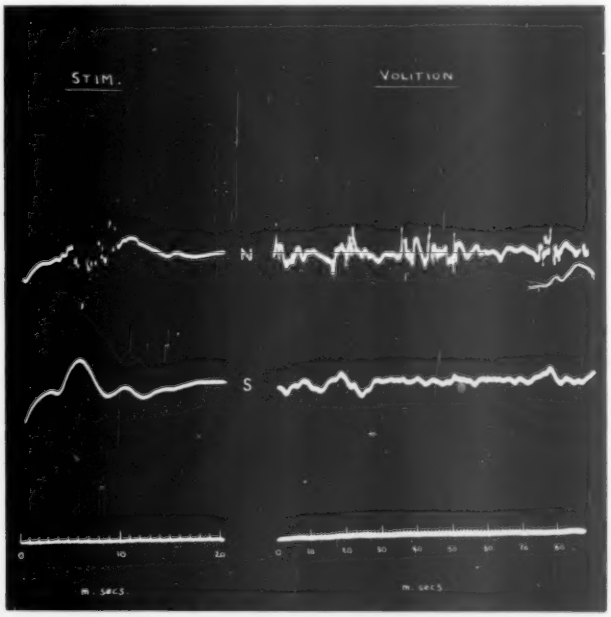

Fig. 1 — Electromyographic tracings simultaneously recorded by means of needle electrodes (N) and surface electrodes (S) from tibialis anticus in the case of a neuropathy — on the left during stimulation of the lateral popliteal nerve in the popliteal fossa and on the right during full volitional activity. Note the absence of the higher frequencies so important in diagnosis in the lower tracing under both conditions.

what can be obtained on volition. Indeed, normal responses on stimulation may occur in the presence of complete paralysis. Such a paradox may be due to the existence of neurapraxia above the level of the stimulation or to the impairment of synaptic or internuncial transmission in the cord or brain without lower motor neuron degeneration.

Failure to obtain a response on nerve stimulation at one level should not be too readily interpreted as a sign of complete motor neuron dysfunction. The threshold of all fibers at that particular level merely may be inaccessibly high.

From neurophysiologists we learn that the caliber of the axon determines both its excitability and the rate of conduction along it: both decrease with a reduction of caliber.

Paul Weiss[1] has, moreover, convincingly demonstrated by experiments that the axoplasm of a nerve fiber is formed in the perikaryon and is propelled from there along the axon to its terminal ramifications where it undergoes a metabolic dissolution.

The concept of a motor neuron as a hydraulic system consisting of a central axoplasm generator and pump, joined to a peripheral consumer by a duct is an interesting one. While it does not solve all problems, it certainly suggests possible explanations for some interesting phenomena encountered and may in the long run facilitate their interpretation.

Clearly in such a system the amount of axoplasm to reach the terminal portions of the axon and neurofibrils depends not only on the balance between the rate of production and the rate of consumption but also on the cross section of the lumen and the presence of any obstruction to flow, possibly even on leakages or disintegration in the transmission.

It would seem from experience that local compression of a nerve fiber can attenuate the calibre of the axons and consequently locally reduce the velocity of conduction and the excitability. This situation I have called "axonostenosis."[2] It further appears that persistent localized axonostenosis may in the long run produce an axoplasmic depletion with a consequent attenuation of the axon diameter along the whole stretch of the fiber distally to the constriction. This widespread secondary phenomenon I have called "axonocachexia."[2] In its presence, the raised threshold of excitability and the reduction of conduction velocity affect the whole distal portion of the fiber.

With these concepts in mind, let us now return to the nerve trunk which we were stimulating, and let us suppose that instead of consisting solely of normal fibers it contains a small number of cachectic fibers. In that case, the response pattern for liminal and near-liminal stimuli will be much the same as before but on substantially increasing the intensity of the stimulus, so as to affect the cachectic fibers, an additional delayed response will be observed — delayed, of course, because of the reduction of velocity distally. In normal nerves, the range of velocities along different fibers is sufficiently narrow to cause the action potentials of the excited muscle fibers to summate into a single neat diphasic or triphasic potential with a period of anything up to 10 or 12 milliseconds.

In the case of axonostenosis and to a greater extent of axonocachexia, the range of thresholds and of velocities is much wider. This results in a considerable disproportion between the liminal and maximal stimuli and in a marked scatter of the response, the latter being presumably a manifestation of the increase in range of differential conduction velocities.

The differences characterizing normality and axonocachexia are impressively illustrated when one branch of a nerve is compressed. Simultaneous electromyographic pick up from a defectively and a normally innervated muscle during stimulation of the common nerve trunks clearly shows temporal dispersion in the one and the well integrated potential in the other (fig. 2).

It should be noted in cases of compression that above the level of the lesion the nerve fibers are normal. Consequently stimulation at all levels above this produces substantially similar patterns but with appropriate latency variations.

On the other hand, stimulation above and below the level of the lesion produces two different patterns. The proximal stimulation will excite all the fibers since all are normal at that level and the resulting pattern will be distorted solely by the differential velocities appertaining to the variously affected fibers distally to the lesion. The response on distal stimulation will, on the other hand, be further modified by the larger range of thresholds with some so high as to be out of reach (fig. 3).

By judicious tests, the level of a peripheral lesion can be ascertained with some degree of accuracy. It is frequently possible in a report to state that a nerve was tested by stimulation at various levels — say the wrist, the elbow, in the axilla and in the supra clavicular fossa— and that the results pointed to the existence of a lesion between two of the points of stimulation or below all of them. Or, alternatively, that the results eliminated the probability of a lesion below any of these points of stimulation but did not exclude the possibility of a more proximal one — say at root or cord level.

I should like to close this particular theme on a clinical anecdote of which the circumstances momentarily sorely tried my faith.

A patient with a history of multiple traumata, including a left shoulder injury and a radial nerve paralysis, was referred to me for electrodiagnostic investigation of the latter condition. An x-ray of the left shoulder was available and showed gross changes, suggesting the nerve lesion was at that level (fig. 4).

Stimulation of the radial nerve just above the elbow joint produced no visible response, but stimulation above the middle of the arm resulted in a barely detectable flicker in brachioradialis. The concomitant electromyographic pattern showed signs of gross scatter but it roughly had the same configuration for stimulation in the upper arm and at Erb's Point (fig. 5). Moreover, the dif-

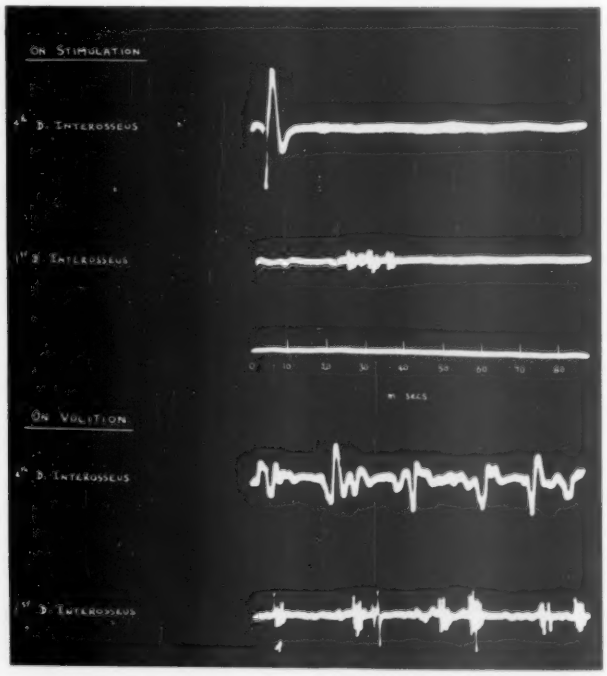

Fig. 2 — Electromyographic tracings simultaneously recorded from the first and fourth dorsal interossei on stimulation of the ulnar nerve at the wrist and on volitional activity, in a case of a lesion of the deep palmar branch of the ulnar nerve. Note the scatter and the exaggerated latency in the first dorsal interosseus response.

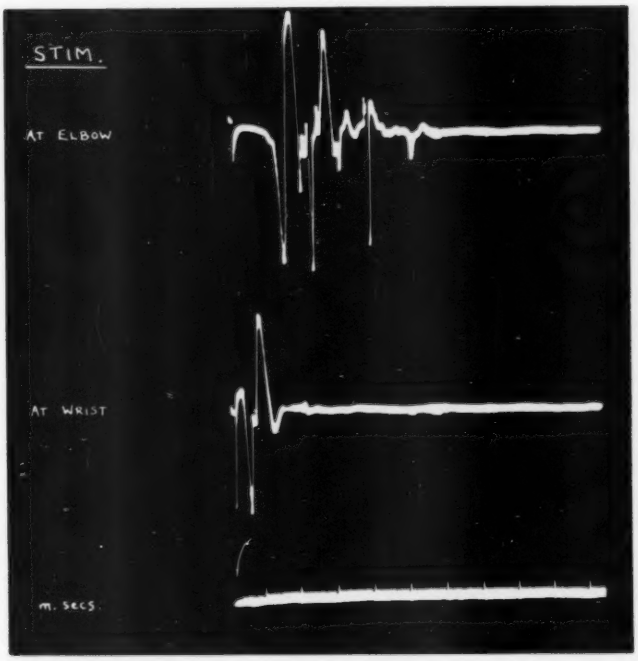

Fig. 3 — Electromyographic tracings recorded by means of a needle electrode in the first dorsal interosseus on stimulation of the ulnar nerve at the wrist and the elbow. The presence of a lesion between the two points of stimulation is deduced from the scatter of the response on stimulation above the level of the lesion and the simpler pattern on stimulation below the level of the lesion. The thresholds of the nerve fibers giving rise to the latter part of the complex may have been too high to effect a response in them at the lower level.

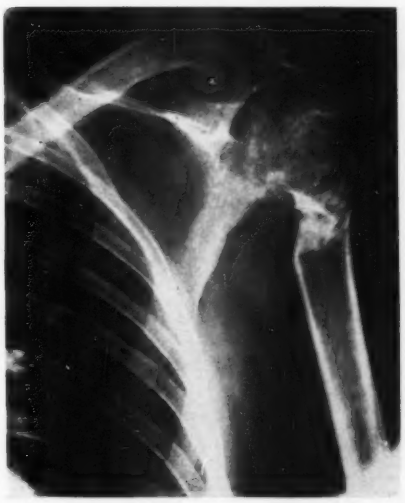

Fig. 4 — X-ray showing gross changes in shoulder joint at the level of which the radial nerve involvement was suspected.

ference in the latencies suggested that the velocity of conduction was normal between these two points of stimulation — that is at the significant level of the damaged shoulder. Everything — the differential velocities of conduction and the high thresholds distally — pointed to a lesion in the lower half of the arm producing both axonostenosis and axonocachexia. To my immense relief a further x-ray of the humerus showed a fracture of the shaft (fig. 6).

It must not be thought that mechanical involvement of the nerve is the sole cause of a reduction in conduction velocities or scatter. Some of the most marked instances of slowing down of nerve impulses occur in neuropathies such as Charcot-Marie-Tooth's and Sottas-Dejerine's diseases. They are also encountered in polyneuritis and leprosy.

Although scatter can be explained on the grounds of differential velocities due

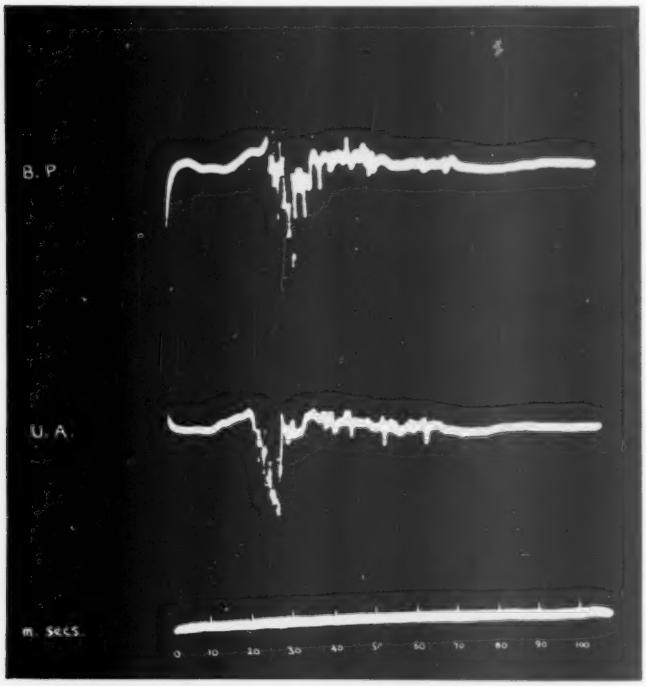

Fig. 5 — Electromyographic tracings of responses obtained in brachioradialis on stimulation of the radial nerve in the upper arm (U.A.) and of the brachial plexus (B.P.). No response could be obtained on stimulation of the radial nerve in the lower part of the arm. Note the rough similarity of both responses and the normal interval between the exaggerated latencies.

Fig. 6 — X-ray of the humerus of the patient to whom figures 4 and 5 apply. A lesion of the radial nerve at the level of the fracture of the shaft explained the electrodiagnostic findings.

to axonocachexia in neuropathies, it would at first sight appear more difficult to do so in primary myopathies where it frequently is observed, but vital staining of biopsy specimens has shown that changes are to be found in the terminal portions of the axons.

Four brothers, unmistakable myopathics on clinical grounds, showed this scatter (fig. 7). Muscle biopsies were performed by Dr. Violet MacDermot, who commented that the routine staining in each case showed the changes generally associated with advanced myopathy, but that the methylene blue stained sections showed degenerative changes and increased branching affecting the distal nerve fibers. A number of fine beaded fibers were seen and many fibers were observed to wander for long distances and apparently end blindly. Moreover, motor end plates showed variation in size and many exhibited degenerative changes.

Whether these neurologic departures from normality are sufficiently gross to account for the degree of temporal dispersion in every case is not yet established. It is, of course, tempting to apply the notion of cachexia to atrophied muscle fiber to explain this phenomenon in myopathy. Alas for such simplification, Buchthal et al[8] have deduced from experimental work that the velocity of propagation of action potentials along muscle fibers remains surprisingly uniform under widely different conditions. It may, therefore, be necessary to examine the possibility of differential delays occurring at the neuromuscular synapse or in the subneural apparatus itself.

What emerges from this assortment of considerations is that for an examination to yield the maximum information there should be available, in addition to provision for the more classical muscle and nerve testing and the more orthodox electromyography, facilities for electromyographic pick up in a distal muscle during stimulation of its motor nerve at intervals along its course. Ideally, the examination would start with simultaneous

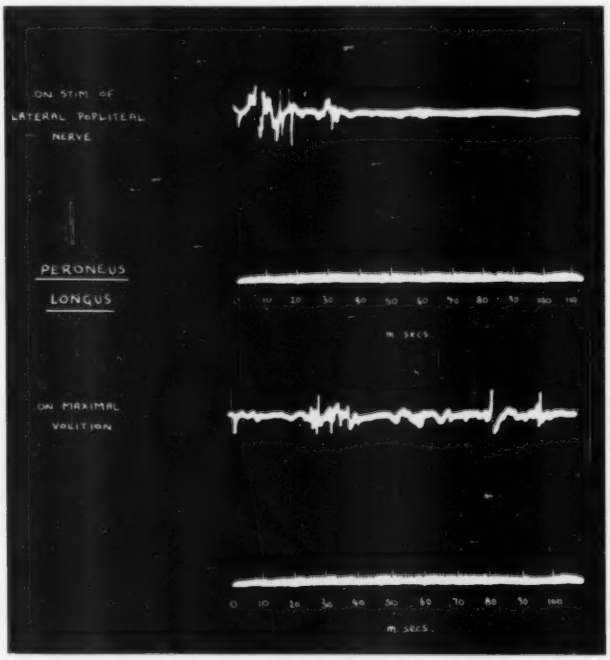

Fig. 7 — Electromyographic tracings from the peroneus longus on stimulation of the lateral popliteal nerve showing dispersion over a period of about 35 msecs. and on volition showing the typical myopathic pattern in a case of dystrophy.

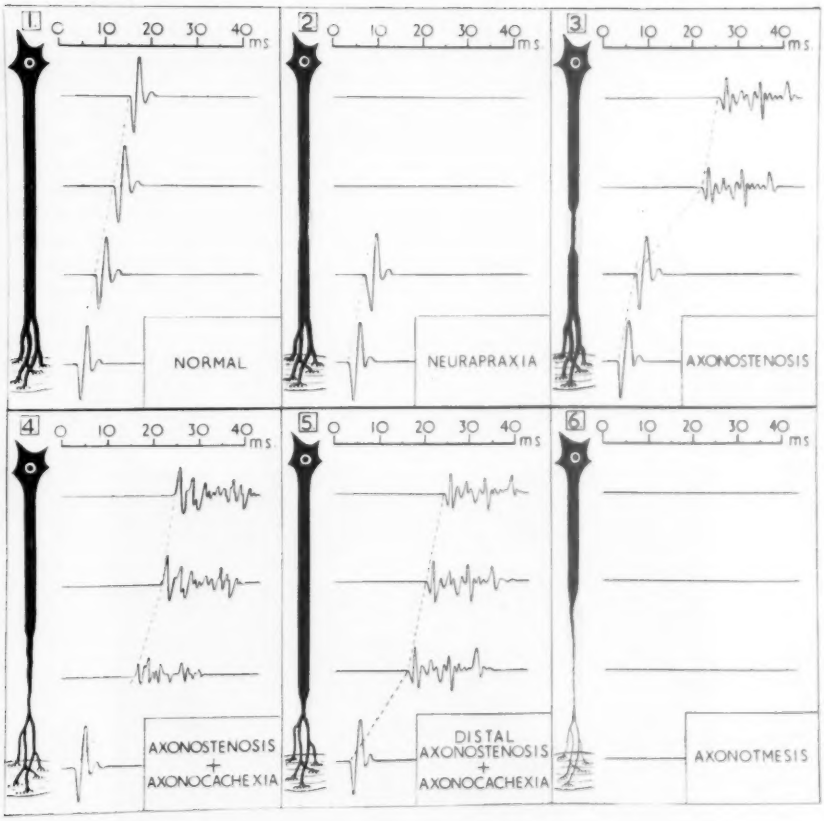

Fig. 8 — Diagrammatic illustration of six possible conditions that may obtain in a motor neuron and the kind of response that would result from stimulating a complex of each type at various levels above and below the lesion. The shaded areas indicate the affected stretch where reduced or absent excitability and conduction defects would prevail. The slope of the broken line is a measure of the conduction velocity between the various points of stimulation. The lowest response in each case represents the result of hypothetic simultaneous stimulation of all the axonbranches at their most distal point.

stimulation of all the neuromuscular junctions in the explored muscle and end with simultaneous stimulation of all the relevant anterior horn cells in the cord. But not only are the two extremes impracticable but nerves are not readily accessible for stimulation save in regions where they are superficial.

Figure 8 epitomizes in diagrammatic form the electrodiagnostic features which could be expected in the six main situations which may be encountered in motor nerves. They range from normality to axonotmesis. Two assumptions have been made: (a) that all the fibers composing the nerve are similarly affected, albeit to different degrees, and (b) that the most distal portion of all the neurons could be stimulated simultaneously so as to give rise to the response curve depicted at the bottom of each of the six panels. Any combination and variation of these may, of course, be encountered.

The electrodiagnostic equipment which has been designed and built for me by Peter Styles provides the necessary facilities for magnetic storage of electromyographic responses to nerve stimulation at as many as seven different levels and for their subsequent display on a long persistence cathode ray tube or for the photographic recording of responses selected for their significance.

Failing the impracticable ideal, the velocity of conduction still can be expressed in the shape of slopes by a compromise in which a family of curves is built up either from photographic records or on the screen of a storage tube of the Skiatron or Memotron type. To this end, the responses are stacked in such a way that their distances from the base line are respectively related to the distances of the point of stimulation from the pick-up needle electrode (figs. 9, 10). A useful alternative is to have a cork board with graph paper on which map tacks can be linked by strings fixed in the top left hand corner and fitted with weights at the other end.

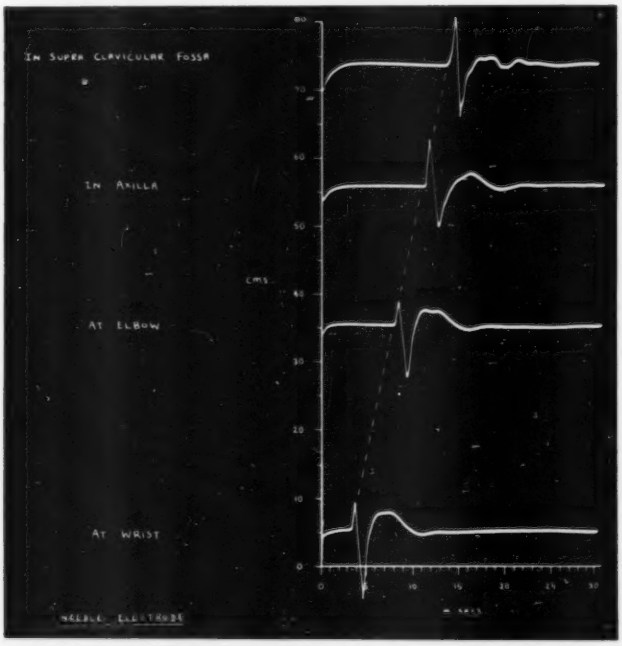

Fig. 9 — A family of electromyographic tracings from the abductor minimi digiti obtained on stimulation of the ulnar nerve at the wrist, the elbow, in the axilla and in the supra clavicular fossa. The curves are stacked so that their distances from the base line are related respectively to the distances of the point of stimulation from the pick-up electrode (6 cm., 35 cm., 55 cm., and 74 cm.). The slope is a measure of the conduction velocity which here is normal and uniform throughout.

The distances are measured along the ordinates and the latencies along the abscissa (fig. 11).

When carrying out this kind of investigation the contraction of normal muscle in the neighborhood can give rise to spurious responses, particularly where the amplifier is used at high gain.

These must be recognized. For instance, when exploring the first dorsal interosseus, as long as the individual stimulation of the ulnar nerve is possible — at the wrist and elbow — the response is related to the first dorsal interosseus only but this differentiation is well nigh impossible when stimulating in the axilla and supra clavicular fossa. Under these conditions an additional response is obtained not only in muscles of the arm and forearm but also of the thenar eminence. The records then may show signs of this unwanted activity which for obvious reasons precedes the material one (fig. 12).

By tracing the genuine response curve on a piece of cellophane and superimposing it on the complex curve, the spurious content frequently can be recognized and consequently ignored. Again, the massive responses resulting from central stimulation may cause jerking of the whole limb which may alter the position of the needle electrode in the muscle or even dislodge it.

A check easily can be made by resorting once more to stimulation of the nerve at the most distal level and comparing the response with the one obtained in the first instance.

In my initial excursions into the field of electrodiagnosis I was exceptionally fortunate in finding encouragement and help from my colleagues, particularly the neurologists. My more recent excursions have been made more stimulating by technical developments in the electronic field and by the large number of cases on which biopsies have been performed and examined after vital staining with methylene blue. I feel that this invitation to give the Coulter Memorial Lecture is a very generous recognition of my

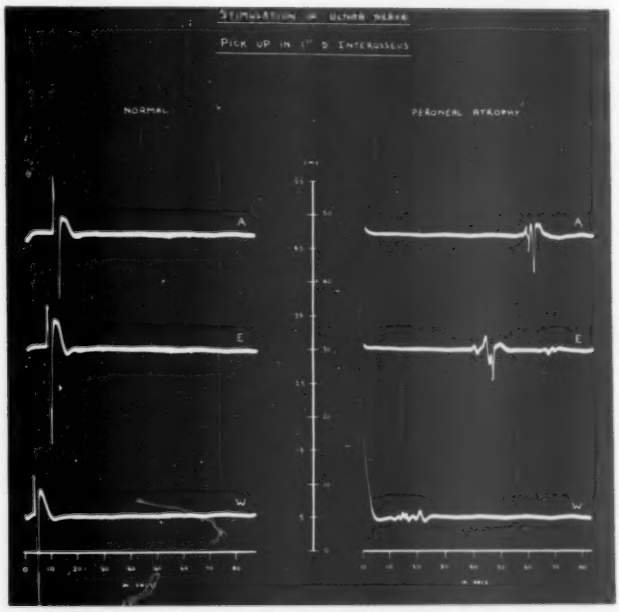

Fig. 10 — Two families of curves resulting from the stacking of responses from the first dorsal interosseus on stimulation of the ulnar nerve at the wrist, elbow and axilla in the normal (left) and in a case of Charcot-Marie-Tooth's disease (right). Note the normal latencies and the substantial similarity in the responses for stimulation at different levels in the normal as opposed to the exaggerated latencies and dissimilarities of the responses in Charcot-Marie-Tooth's Disease.

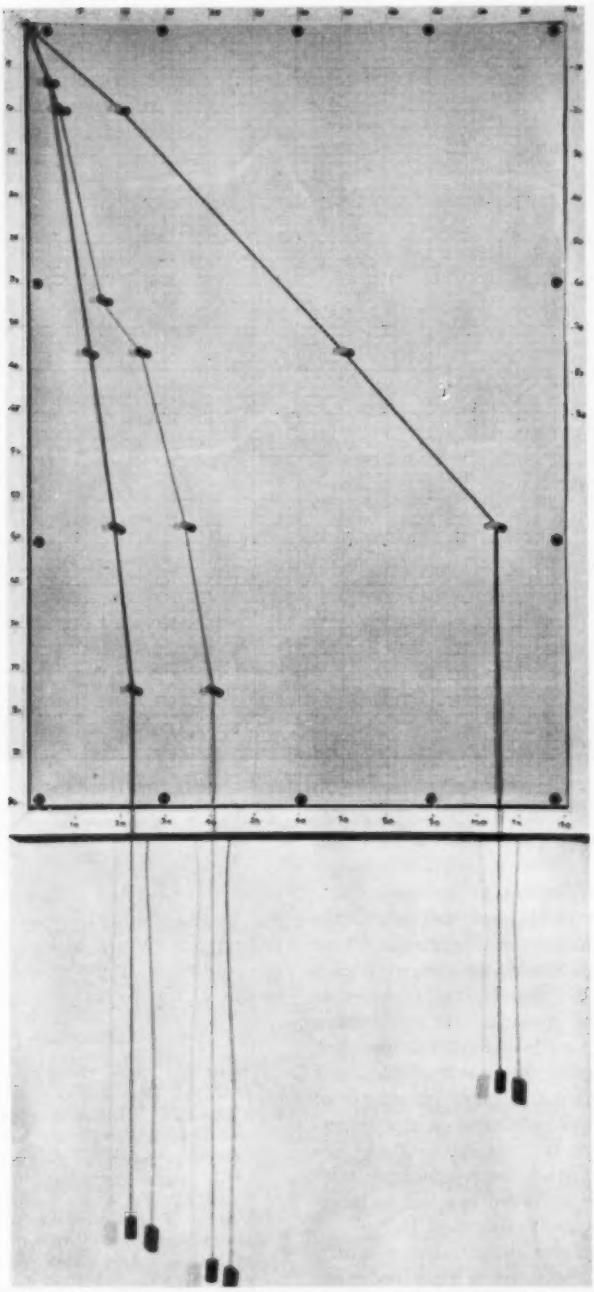

Fig. 11 — A cork board covered with centimeter graph paper provides an expedient method of plotting conduction velocity curves when map tacks mark the latencies along the abscissa (1 cm. per msec.) for the respective distances (measured in cms.) of the points of stimulation from the needle electrode along the ordinate. The slopes are obtained by joining the tacks by string.

(A) *(first string)* Normal conduction velocity along the ulnar nerve to abductor minimi digiti.

(B) *(second string)* Shows local retardation of impulses along the ulnar nerve at the level of the elbow on pick up in the first dorsal interosseus.

(C) *(third string)* Grossly reduced conduction velocity along the ulnar nerve in a case of Charcot-Marie-Tooth's Disease.

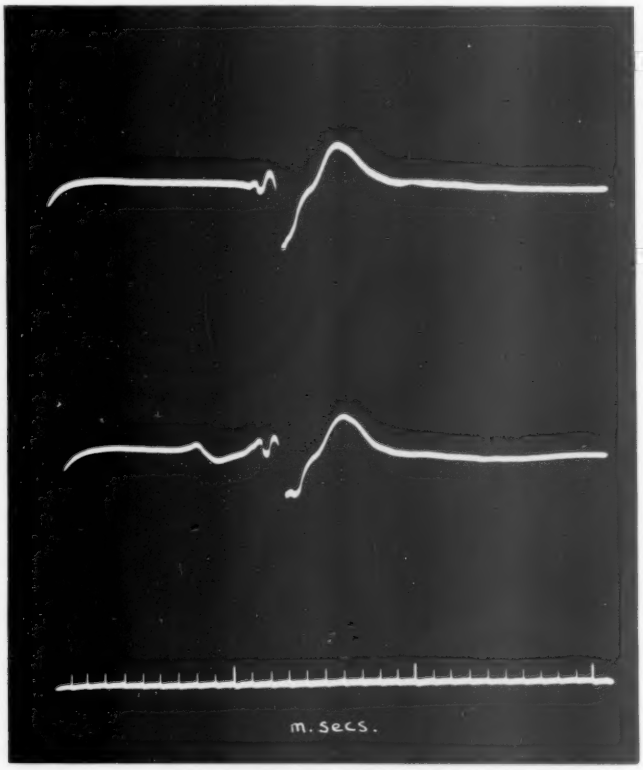

Fig. 12 — Electromyographic tracings from the first dorsal interosseus on stimulation of the ulnar nerve in the axilla. The upper tracing shows the response with a latency of 11 msecs. when the ulnar nerve only was stimulated. The lower tracing shows the appearance of a precursory spurious response which gives rise to a false latency of eight msecs. when the median nerve was also stimulated.

meager contributions to the subject.

I must hope I have not given the impression that electrodiagnosis is a kind of exercise in electrophysiology or even in electropathology. I should prefer to think that my revisiting electrodiagnosis in your company has created the helpful, albeit naive concept that the locomotor system is a tribal society composed of excitable individuals capable of interacting and of communicating with one another by means of their own bush telegraphs which we have learned to intercept, but not yet to interpret fully.

As in the case of jungle drums, which are intelligible to the initiate only, we must make further efforts to learn both the language and the way of promoting chatter if we yearn to know more about the traditions, trials, troubles and tribulations of this remarkable society.

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Information relative to securing reprints of this study may be had by checking the Reader Service column on page iv of this issue.

Etiology of Decubitus Ulcers

Michael Kosiak, M.D.
Minneapolis

● Eighty separate experiments were performed in an attempt to accurately determine the effect of both constant and alternating localized pressure on normal and enervated muscle. Localized pressures were applied over muscular tissue and the relationship between microscopic changes in the muscle and time and intensity of pressure was noted. Data compiled demonstrated the marked susceptibility of tissue to relatively low constant pressures for short periods of time and the somewhat greater resistance to change following the application of equal amounts of intermittent pressure. This was true of both normal and denervated tissue. A critical time interval at which pathologic change occurs in both normal and denervated skeletal muscle following the application of pressure was noted.

Decubitus ulcers are one of the major problems confronting any physician who is called upon to supervise the care of the severely disabled or debilitated patient. Every clinician is well aware of the complications which often manifest themselves following the occurrence of ulceration in the chair- or bed-ridden patient. Decubitus ulcerations not only prolong the morbidity and interfere with the rehabilitation and maintenance of these people but they also may frequently be implicated as a major contributing factor leading to the patient's demise.[1]

Ulceration of the skin especially over bony prominences has undoubtedly plagued the disabled and debilitated patient since the beginning of man.[2] Before the advent of antibiotic therapy, secondary infection of the ulcerations led to early death, whereas today the patients usually survive for prolonged periods of time in spite of the ulcerations. Improved medical, nutritional, and environmental factors have increased the life span of man with the result that there are more persons than ever before living to a relatively old age. This presents a problem in that a greater number of patients with cerebral vascular disease, malignancies and neurologic disorders are being cared for in our hospitals and nursing homes. With the increase in the average age of the population, as well as the improvement in medical facilities, the medical profession is being faced with the problem of maintaining and rehabilitating the elderly and severely disabled person.

In spite of the relatively widespread occurrence of ulcerations in the general hospital population and the almost inevitable occurrence in the patient with spinal cord injury, no agreement exists as to the basic underlying cause of the ulceration.[1, 3-5] This is undoubtedly due to the fact that very little basic research has been done regarding the etiology of decubital ulcers. Most of the prevailing evidence has been derived from clinical observations.

Decubital ulcerations are localized areas of cellular necrosis. Normal cell metabolism is dependent on the receipt of nutrients and the elimination of metabolites. Any condition which interferes with this exchange will affect the function of the cell. The circulating peripheral blood fulfills the metabolic needs of the cell so that any alteration in the circulation is reflected in cellular changes. Severe or prolonged circulatory interference ultimately leads to death of the cell.

Because ulcerations occur almost exclusively over bony prominences which have been subjected to excessive pressures for varying lengths of time and because ulcerations almost inevitably will heal when pressure is removed, it would appear that ischemia caused by supracapillary pressures is one of the primary factors in the production of decubitus ulcers.

Review of the Literature

To effectively evaluate the physiologic changes which occur as a result of the application of pressure it would appear that the three basic problems which must be investigated are: (1) pressure, (2) tissue ischemia, and (3) capillary changes.

1. *Pressure.* It is difficult to evaluate

This contribution received the R. D. Grant Award for the best study on etiology of decubitus ulcers.

Instructor, Department of Physical Medicine and Rehabilitation, University of Minnesota Medical School, Minneapolis, Minn.

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the effect of pressure per se on the physiologic function of the living cell without involving the circulation to the cell. Catell[6] carried out experiments on isolated tissues, enzymes, and unicellular organisms in an attempt to determine the physiologic effects of pressure on tissue under conditions in which the effect produced could be attributed only to the pressure and not to the interference with receipt of nutrients or the elimination of waste products of cell metabolism. The pressures were applied through a fluid medium. Pressures in excess of 250,000 pounds/square inch were necessary at times to produce significant changes in cellular function. However, pressures as low as 260 mm. Hg were observed to stop nerve conduction in a few minutes.

2. *Acute Ischemia.* Early impetus for the investigation of pathologic changes arising from ischemia of voluntary muscle was provided by Volkmann,[7] who described the necrosis of muscle due to ischemia induced by compression of the arteries with constrictive dressing. However, early workers, because of the interest in the pathogenesis of Volkmann's contractures, devoted most of their attention to the chronic lesions arising from ischemia of voluntary muscle and gave little attention to the initial phases or changes that occurred in the first 24 hours.

Brooks[8] noted that the application of 130 mm. Hg pressure by means of a plethysmograph to the tail of a rat for approximately 18 hours produced massive necrosis in all instances while a pressure of 130 mm. Hg for 17 hours produced gangrene in only seven of nine cases. However, when pressures of 100 mm. Hg were applied for 48 hours, gangrene of the entire tail was again noted. Ulceration generally was first noted two or three days after the application of pressure. Microscopically, there was a thickening of the epithelium and the muscle showed evidence of degeneration, myositis, and fibrous replacement. Harman[9] reported that ischemia of two to four hours duration produced by ligation of the major arteries to the extremity of a rat resulted in microscopic pathologic changes which readily were recognized. The alteration in structure was first observed in muscles of animals subjected to ischemia for at least four hours. This was characterized by individualization or separation of fibers, regression of longitudinal striations and enhancement of cross-striations. Muscles of the extremities were exposed and tested in situ for contractility with a Faradic current applied directly to the muscles through metal electrodes and the contractions were graded relative to those in the normal limb. Weakness or absence of contractility generally preceded and accompanied the pathologic changes. Harman concluded that this physiologic change confirmed the pathologic phenomena which was present.

In an attempt to determine the difference between arterial and venous occlusion, Brooks[10] isolated the rectus femoris muscle of dogs and then ligated the single artery, vein or nerve which supplied the muscle. Microscopic examination of tissue taken from dogs in which the muscle was completely separated from arterial supply for periods of seven to 60 days showed slight degenerative changes and in no instance was there a marked inflammatory reaction of fibrous tissue in the muscle. Because of the appearance of hemorrhage, edema, degeneration of muscle fibers and acute inflammatory process following the ligation of the vein, the author concluded that the changes noted were initiated by capillary damage produced by greatly increased capillary pressure.

Harman[11] more recently noted that complete arterial ischemia of the extremity of a rat for periods of four to four and one-half hours was followed by dilatation of the arteries in the ischemic limb and patency of the veins following the removal of constriction. This led the author to believe that degenerative muscular changes were probably due to severe capillary damage. Because of this capillary damage, stasis and alteration of the normal permeability, there was a decrease in the inflow of blood to the cellular units and a considerable depression of the rate of exchange of metabolites.

Husain[12] recently noted microscopic changes in the muscles of a rat when

pressures as low as 100 mm. Hg were applied for as little as two hours. While no gross changes were noted, 24 hours after pressure was applied, there was microscopic evidence of cellular infiltration, interstitial capillary hemorrhage, and various stages of cellular degeneration. Pressures of 100 mm. Hg for six hours produced similar but more severe changes. I[13] have recently reported that microscopic examination of tissue obtained 24 hours after the application of only 60 mm. Hg for one hour showed cellular infiltration, extravasation, and hyaline degeneration. Tissue subjected to higher pressures for longer periods of time showed muscular necrosis, hyaline degeneration and venous thrombosis as well as cellular infiltration and extravasation.

3. *Capillary Changes.* With this implication of the minute vasculature of the tissue, it would seem that some discussion and review of the circulatory bed is indicated.

Zweifach and Metz[14] reported observations on the skeletal muscle of the rat. They noted arterial arcades from which metarterials branched at right angles and these in turn divided into capillaries which lay on the surface of the small bundles of muscle fibers. The capillaries usually lay along the axis of the muscle fibers and were 40 to 50 microns apart.

Most authors making direct observations on minute vessels report a phenomenon which has been designated as "active vasomotion." This is an intermittent ebb and flow through the network because of the opening and closing of the metarterials and precapillary sphincters. Nicol and Webb[15] expressed the view that the slow vasomotor changes were due mainly to local changes in tissue and that faster vasomotor changes were probably due to neural influences since they were abolished by denervation. They suggested that active vasomotion may be the main determinent of capillary pressure.

Burton and Jamada[16] demonstrated that the rate of flow through minute vessels was related to the perfusing pressure. They found the relationship between the blood flow and the transmural pressure to be approximately linear through most of the pressure range. However, as the transmural pressure was reduced, there was a rapidly progressive decrease in blood flow and the flow stopped while the transmural pressure was still at 20 to 40 mm. Hg. The level of transmural pressure at which the blood flow stopped was called the "critical closing" pressure. This "critical closing" pressure could be produced either by an increase in externally applied pressure or a decrease in intravascular hydrostatic pressure.

Nichol[16] has demonstrated remarkable instability in capillaries at low perfusion pressures with cessation or temporary reversal of flow at a low positive pressure. This closing pressure was found to range from three to six centimeters of water in the hind leg of a frog. Burton[17] noted complete cessation of arterial flow in the forearm of man at times when the external pressure to the forearm by means of a water plethysmograph was 70 mm. Hg less than the subject's mean arterial pressure.

Landis,[18] using the microinjection method for determining blood pressure in single capillaries, found the average pressure in the arteriolar limb to be 32 mm. Hg. He noted increases in maximum capillary pressures to 60 mm. Hg during hyperemia and 50 mm. Hg during histamine flare.

Much information exists in the literature regarding the phenomenon of reactive hyperemia which manifests itself following several types of stimuli. This hyperemia is generally regarded as a normal protective response and is noted routinely following arterial occlusion.

Much of the early work regarding reactive hyperemia was carried out by Lewis and Grant[19] as well as by Goldblatt[20] who did their work at approximately the same time. They showed that occluding a portion of an extremity for five seconds or more generally produces a reaction. The reaction is proportional to the duration of occlusion and to the temperature of the limb. The duration of the reaction generally increases with the time of occlusion up to one hour and generally lasts one-half to three-fourths

as long as the occlusion. They also demonstrated that hyperemia was not dependent on central innervation of the blood vessels since it would occur in tissue which was completely denervated. It would therefore appear that reactive hyperemia is not due to changes in intravascular pressure but to accumulation of some products of metabolism during the periods of circular disturbance.

Recent work by Landis[21] and Henry[22] would tend to implicate anoxemia as the primary reason for reactive hyperemia. Landis showed that a complete ischemic anoxia of three minutes duration would cause temporary damage to the capillary of frog's mesentery and produce a movement of fluid through the capillary wall which was four times the normal rate.

Purpose of Study

This study was undertaken in an attempt to accurately determine the effect of both constant and alternating localized pressure on normal and denervated muscle. Localized pressures were applied over muscular tissue and the relationship between microscopic changes in the muscle and time and intensity of pressure was noted.

Methods

Forty albino rats ranging in weight from 300 to 400 grams were subjected to localized pressures ranging from 35 to 240 mm. Hg for periods of one to four hours. All animals were anesthetized with pentobarbital (Nembutal, 30 mgm./kgm. body weight) during a test period. The animals were placed in a prone position with the hind extremities secured in a relaxed abducted position.

Constant pressures were applied to the hamstring group of muscles of 12 normal rats for a predetermined length of time. Eight normal rats were subjected to alternating pressures for equal periods of time with the pressure being relieved every five minutes for a period of five minutes.

Mid-thoracic section of the spinal cord was performed on a group of 20 animals. Twelve animals in this group were subjected to constant pressures while alternate pressures, at five minute intervals, were applied to the other eight animals.

All animals were returned to their cages following completion of the test. Twenty-four hours later the animals were sacrificed and the belly of the lateral hamstring muscle was removed. The tissue was fixed in Bouin's solution for a period of six hours, sectioned to a thickness of five microns and stained with hematoxylin and eosin as well as trichrome stain.

Pressures were applied by an air-driven piston consisting of a 20 cc. hypodermic syringe which was inverted and stabilized over the test area as described in a previous study.[13]

Tissue pressures were measured by means of a Statham P23A physiologic transducer which was connected to a 20 gauge needle inserted into the muscle. The needle had five openings bored into the lateral surface within a distance of one centimeter from the tip. To assure contiguity between the fluid being tested and the fluid within the system saline was infused at the rate of 4.6 cc. per hour from a constant injection pump. It was thought that this low rate of flow would not influence the tissue pressure being measured. Pressures were measured with the needle horizontal to the plunger head and all values were recorded on a Sanborn polyviso recorder (fig. 1).

Results

Eighty separate experiments demonstrated a marked susceptibility of tissue to single applications of moderate pres-

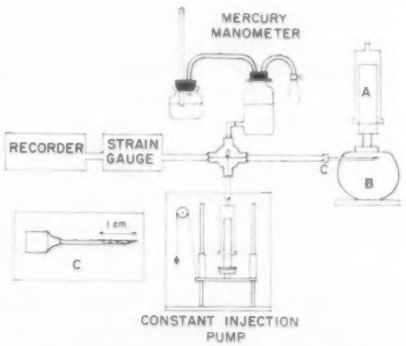

Fig. 1 — Apparatus used to measure tissue pressure: A, 20 cc. hypodermic syringe, inverted; B, animal's leg; C, 20 gauge needle.

sure for relatively short periods of time (table 1). Microscopic examination of tissue 24 hours after the application of pressure demonstrated varying degrees of involvement in both the normal and paraplegic rats. Characteristic pathologic changes noted in individual muscle fibers consisted of decrease or loss of cross-striations and myofibrils, hyalinization of fibers, neutrophilic infiltration as well as floccular changes with phagocytosis by neutrophils and macrophages (figs. 2 and 3). Isolated muscle fiber involvement was designated as a minimal change. Moderate change indicated involvement of up to 10 per cent of the muscle fibers and marked change referred to involvement of more than 10 per cent of the fibers examined with the presence of edema and inflammatory changes.

No changes were noted in the specimens which were subjected to pressures of 35 mm. Hg for periods of time up to four hours. This was true of both the normal and paraplegic rats. The application of varying pressures up to 190 mm. Hg in the normal rat and 155 mm. Hg in the paraplegic rat for one hour did not produce any noticeable microscopic change in the tissue. However, the application of 70 mm. Hg pressure in both the normal and paraplegic rat produced changes after two hours. This is in complete agreement with the work of Husain.[12] Working with dogs, we have shown that the application of 60 mm. Hg pressure for one hour produced edema, cellular infiltration and extravasation.[13]

The application of alternating pressures, whereby the tissue was completely free of pressure for five minute intervals, showed consistently less change or no change when compared with tissue subjected to an equivalent amount of constant pressure. This was true even at pressures as high as 240 mm. Hg for three hours.

There appeared to be no consistent increase in susceptibility of the muscle in the paraplegic rats as compared to normal rats at all ranges of pressure. No apparent microscopic difference was

Table 1: Microscopic Changes Noted in Muscle of Animals 24 Hours After Application of Pressure

Pressure Transmitted to Muscle	Time in Hours	Normal		Paraplegic	
		Constant Pressure	Alternating Pressure — 5 min. intervals	Constant Pressure	Alternating Pressure — 5 min. intervals
35 mm. Hg	1	None	None	None	None
	2	None	None	None	None
	3	None	None	None	None
	4	None	None	None	None
70 mm. Hg	1	None	None	None	None
	2	Moderate	None	Moderate	Minimal
	3	Moderate	Minimal	Moderate	Minimal
	4	Moderate	Minimal	Marked	Minimal
115 mm. Hg	1	None		None	
	2	Minimal		Moderate	
	3	Marked		Marked	
	4	Moderate		Moderate	
155 mm. Hg	1	None	None	None	None
	2	Moderate	None	Minimal	None
	3	Marked	Minimal	Minimal	None
	4	Moderate	Moderate	Moderate	Minimal
190 mm. Hg	1	None		Minimal	
	2	Minimal		Moderate	
	3	Marked		Marked	
	4	Marked		Marked	
240 mm. Hg	1	Minimal	None	Moderate	None
	2	Moderate	Minimal	Moderate	None
	3	Moderate	None	Moderate	Minimal
	4	Moderate	Moderate	Marked	Minimal

None — No microscopic change.
Minimal — Involvement of isolated fibers.
Moderate — Involvement of up to 10 per cent of muscle examined.
Marked — Involvement of more than 10 per cent of muscle examined.

noted between control samples of muscle from normal and paraplegic rats.

Seventy to 80 per cent of the applied pressure was transmitted directly to the involved tissue. This was due to the sling or suspension effect of the skin as described previously.[13]

Discussion

These data have demonstrated the marked susceptibility of tissue to relatively low constant pressures for short periods of time and the somewhat greater resistance to change following the application of equal amounts of intermittent pressure. This was true of both normal and denervated tissue.

It previously has been shown[13] in dogs that a definite inverse relationship exists between the amount and duration of pressure which tissue can tolerate before pathologic changes are noted (fig. 4).

Fig. 2 — Muscle of normal rat's leg after application of 115 mm. Hg constant pressure for two hours. The section shows early involvement of an isolated fiber consisting of hyaline degeneration and phagocytosis. Hematoxylin and eosin. X380

Fig. 3 — Muscle of paraplegic rat's leg subjected to 70 mm. Hg constant pressure for four hours. The section shows an isolated fiber undergoing necrosis associated with extensive phagocytosis by neutrophils and macrophages. Hematoxylin and eosin. X170

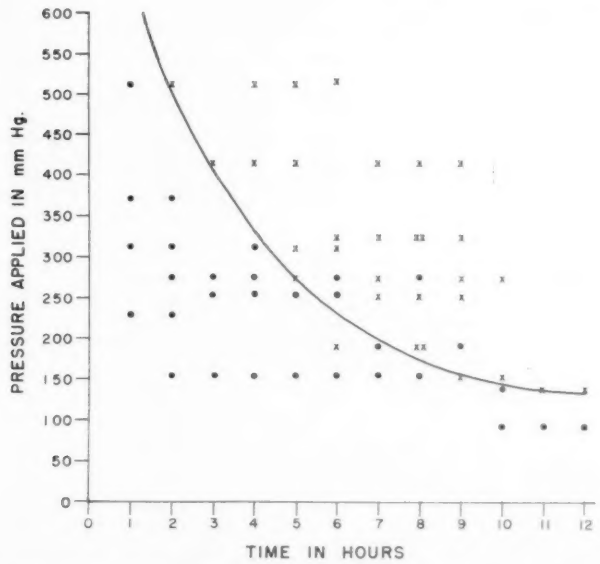

Fig. 4 — Pressure time relationship noted in 62 separate experiments on 16 dogs: X = ulceration; • = no ulceration.

Intense pressures of short duration are responsible not only for interference and perhaps complete cessation of capillary circulation but also for changes in the larger vessels with the result that venous thrombi may be found. The presence of venous thrombosis then interferes with the normal reactive hyperemic vasodilatation after the pressure is removed, with the result that the tissues continue to remain ischemic.

Ulcerations in dogs generally occurred three or four days after the application of pressure. Brooks[8] previously had noted massive necrosis of rats' tails two to three days after pressures had been applied to a rat's tail by means of a plethysmograph. Edema and hyperemia were usually noted immediately following the release of pressure over the test area and generally prevailed for about half as long as the duration of the application of pressure; 24 hours later the skin appeared normal (figs. 5 and 6). Even when ulceration occurred three or four days after the application of pressure, the protective hyperemic response subsided before the edema and inflammatory response of tissue damage was noted. This usually appeared from 48 to 96 hours prior to ulceration and progressed rapidly to actual skin necrosis (figs. 7-10). Ulceration was never noted before three days and in one instance was not noted until nine days following the application of pressure.

Fig. 5 — Hind leg of dog prior to a single application of 300 mm. Hg pressure over the greater trochanter and the lateral aspect of the ischial tuberosity for a period of five hours.

Fig. 6 — Twenty-four hours after application of pressure. Inflammatory change beginning over greater trochanter.

Fig. 7 — Two days after application of pressure. Increasing inflammation over trochanter and beginning inflammation over lateral surface of ischial tuberosity.

Fig. 8 — Three days after application of pressure. Beginning ulceration over both areas.

Harman[11] has demonstrated quite conclusively that pathologic changes following ischemia are due to disturbances in capillary circulation. The fact that changes are noted after a single applica-

Fig. 9 — Five days after application of pressure. Frank ulceration over trochanter with early healing over lateral surface of ischial tuberosity.

Fig. 10 — Seven days after application of pressure. Increased ulceration over trochanter with almost complete healing over the lateral surface of ischial tuberosity.

tion of constant pressure slightly greater than capillary pressure would tend to support this reasoning. The presence of edema and cellular infiltration 24 hours after the application of moderate pressure would indicate moderate changes in capillary permeability probably due to the capillary membrane ischemia. Increasing the degree or duration of ischemia not only increases the changes in membrane permeability but interferes with cellular metabolism to such a degree as to produce cellular necrosis and inflammatory reaction in the muscle tissue.

Husain[12] has demonstrated that microscopic changes produced after the application of localized pressure were due primarily to ischemia. In a group of rats in which the femoral artery had been ligated, microscopic changes were noted after a single application of pressure of only 50 mm. Hg for a period of only one hour. These changes were similar to those noted in rats with normal circulation following the application of 100 mm. Hg pressure for a period of two hours. Production of generalized ischemia in the entire extremity tended to increase the degree of ischemia produced by the local application of pressure.

If any variation existed in the pathologic changes found in the normal rats as compared to those with sectioned spinal cords, the pattern was not consistent. Individual variations were probably due to the lack of sensation and general decrease in muscle circulation.

Regarding the importance of a neurotrophic factor as a primary cause of ulceration, there is very little basic evidence to lend any support to this theory. The fact that ulcerations occur perhaps more frequently in patients with spinal cord injury or peripheral nerve involvement, cannot be denied. However, without implicating a neurotrophic factor, it would seem that the simplest explanation for this occurrence is the fact that sensory function is interfered with so that the patient does not experience pressure and the general circulation to the denervated area is somewhat decreased making the tissue more susceptible to ischemia. The fact that ulceration frequently occurs in a normally innervated area subjected to pressure and that ulcerations in extremities divorced from any neurologic control invariably heal when maintained free of pressure tends to relegate the neurotrophic theory to a secondary if not completely insignificant factor in the production of ulcerations.

The metabolic deficits which manifest themselves following trauma or prolonged immobilization have been well documented by several groups of investigators.[23-27] Though the effects of general metabolic changes on the production and healing of ulcerations have not been demonstrated experimentally, it would seem that healthy, well-nourished tissue not only can survive an insult of any type more readily, but is better able to recover from this insult.

Other contributing factors in the production of ulcerations are edema and anemia. Since the rate of diffusion of oxygen and metabolites from the capillary to the cell decreases in proportion to the distance from the capillary to the cell, it is clear that edema has profound influence on the survival of the ischemic cell. If ischemia is accompanied by anemia and decreased oxygen content in the blood, cellular metabolism is further restricted and the tissue becomes more susceptible to the ischemia.

Because of microscopic degenerative changes which result from the application of only relatively low pressures for short periods of time, it becomes apparent that degenerative reaction and recovery from these changes is probably taking place simultaneously. Where tissue is subjected to pressures for only short periods of time, the normal reactive hyperemic response partially compensates for the temporary ischemia with the result that the tissue does not undergo morphologic degeneration. Even when excessive pressures are applied for a sufficient period of time to result in early degenerative changes, it would appear that complete relief of pressure may often permit restoration of circulation and cellular metabolism without ulceration.

Clinically, even when adequate nursing care is available the incapacitated person is rarely turned oftener than once every two hours; thus, each trochanter, the sacrum or the iliac spine is subjected to supracapillary pressures for two hour intervals at least three times each day. Many bed-ridden patients develop ischemic ulcers on such a regimen. This would indicate that the damage produced during the time that the pressure was being exerted was not completely repaired during the intervals when the area was free of pressure. More frequent turning of the patient would result in more frequent periods of complete relief of pressure during which restoration of cellular function could occur.

Though no measurements of pressure under the sacrum or trochanters while the patient is in the lying position have been reported, the superficial covering is so limited that almost all pressure applied must be transmitted to all tissue depths. Trumble[28] has calculated that if a person's weight were equally distributed over the entire surface available for weight bearing when in the recumbent position, it would amount to less than one-third pound/square inch (17 mm. Hg). However, in an ordinary bed, the weight of the body is borne primarily over certain bony prominences whose combined area is very small with the result that the pressures over these areas undoubtedly exceed capillary pressure.

The weight bearing area available to the patient is considerably less when sitting than when supine; it depends primarily on the sitting posture itself, and to a lesser degree, on the sitting surface available. If the intertrochanteric distance is assumed to be approximately 32 cm. and the anteroposterior sitting surface is the same, the available sitting area is approximately 150 square inches. Since approximately 75 per cent of a subject's total body weight when he is sitting is exerted over this limited area, the pressure would exceed 26 mm. Hg even if it were evenly distributed. But, the brunt of the pressure is borne by a rather limited area immediately under the ischial tuberosities. We have shown that even with a two inch foam rubber cushion, average pressures under the ischial tuberosities and surrounding area generally exceed 150 mm. Hg.[29] If only 50 per cent of this pressure were transmitted to the ischial tuberosity, there would be complete cellular ischemia of all tissue over the bone and ultimate ulceration would only be a matter of time.

Cut-out areas intended to decrease or eliminate pressures over the bony tuberosities only tend to divert more of the weight bearing to the surrounding area. Increasing the thickness of the cushioning to as much as six inches of foam rubber appears to have had little effect on the occurrence of ulceration in the wheelchair patient. Conversely, the more sophisticated, well-informed paraplegic with good upper extremities can remain relatively free of ischemic ulcers by conscientious weight shifting several times each hour regardless of the seat padding which is used. *Since it is impossible to*

completely eliminate all pressure for a long period of time, it becomes imperative that the pressure be completely eliminated at frequent intervals in order to allow circulation to the ischemic tissues.

Summary

1. Skeletal muscle from both normal and paraplegic rats exhibited a high degree of susceptibility to low constant pressures for relatively short periods of time.

2. Microscopic pathologic changes in muscle were absent or less prominent following the application of equal amounts of alternating pressures in both the normal and paraplegic rats.

3. There are no detectable microscopic differences between normal or denervated muscle following the application of either constant or alternating pressure.

4. A critical time interval at which pathologic change occurs in both normal and denervated skeletal muscle following the application of pressure was noted. This critical period was between one and two hours.

5. Microscopic pathologic changes due to the application of pressure consist of edema, loss of cross-striations and myofibrils, hyalinization of fibers, neutrophilic infiltration and phagocytosis by neutrophils and macrophages.

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Information relative to securing reprints of this study may be had by checking the Reader Service column on page iv of this issue.

VERY IMPORTANT

The next examinations, written and oral, of the American Board of Physical Medicine and Rehabilitation will be held in New York City, June 24 and 25, 1961. The final date for submitting application is February 15, 1961. Write to the Secretary, Dr. Earl C. Elkins, 200 First Street, S.W., Rochester, Minnesota, for application.

Relationship of Progress in Speech Therapy to Progress in Physical Therapy

Daniel R. Boone, Ph.D.
Cleveland

● A study described in this paper indicates that patients who are so involved physically and psychologically that ambulation training is not possible, most of the time will not benefit from speech therapy. Among those patients who do well in physical therapy there is an approximate 50 per cent expectancy that improvement in speech will occur. No significant relationship was found between those patients who did well in physical therapy to the progress they made in speech therapy. Except for those hemiplegic and multiple sclerosis patients who do poorly in physical therapy, a prognostic index for speech improvement cannot realistically be based on the patient's present or predicted performance in physical therapy. Another implication found in the study is that among the large population of physically improving hemiplegic and multiple sclerosis patients, it is not possible to predict by physical status alone how well a patient will do in speech therapy. While a significant relationship was found between absence of progress in both speech and physical therapies, there was only a chance relationship between progress in physical therapy to similar progress in speech therapy.

Patients with problems of aphasia or dysarthria frequently receive both speech therapy and physical therapy at the same treatment center.[1] Out of this situation have come such observations as, "if the patient improves in general physical independence after receiving physical therapy, he will also improve in speech and language functions." It also is not unusual in such combined programs to find patients who may improve markedly in speech and language but remain relatively static in limited physical ability.[2] One might logically speculate, however, on a corresponding improvement by the patient in both physical and speech therapies, although there are few documented studies reporting on such progress relationships.

Dysarthria, slurred and inarticulate speech due to motor dysfunction of any or several of the components comprising the oral musculatures, might be expected as a motor disturbance to decrease in severity in a similar manner to a decrease of general motor impairment.[3] For example, as the hemiplegic becomes more independent in ambulation, he would experience a corresponding improvement in clarity of speech. The aphasic patient, on the other hand, possesses a symbolic disturbance in language function, which we might postulate would tend to be somewhat independent of improvement in physical status.[4] Many patients who remain profoundly aphasic may experience complete return in the involved extremities of motor and sensory functions.

This study investigated the relationship of progress achieved in speech/language functions by 153 patients (hemiplegic, multiple sclerosis) to their degree of physical independence after completing physical therapy. As each speech therapy patient at Highland View Cuyahoga County Hospital, Cleveland, Ohio, finishes with this therapy he is given one of four progress ratings:

1. No observable progress.
2. Slight progress observed on comparative testing.
3. Speech progress easily demonstrated with better speech intelligibility.
4. Excellent speech progress approaching near normal or normal speech clarity.

In this study these ratings then were compared with an evaluation of functional performance by the patient completing physical therapy, who receives one of five ratings:

1. Bed bound.
2. Wheelchair bound, requiring assistance in transfer and transport.
3. Wheelchair bound, independent.
4. Ambulatory, but guided, assisted or supervised.
5. Ambulatory, completely independent.

It thus was possible to compare the patient's speech/language performance after speech therapy to the degree of physical independence observed after physical therapy was discontinued.

Director, Clinical Speech Pathology, Cleveland Hearing and Speech Center, Cleveland, Ohio. Formerly with the Highland View Hospital, Cleveland.

Read at the 3rd International Congress of Physical Medicine, Session on Medical Problems Diagnosed or Treated by Physical Medicine, Washington, D. C., August 23, 1960.

Findings

During the past year 153 patients at Highland View Hospital were seen jointly by specialists in speech and physical therapies, receiving improvement ratings in both therapies. Of this number, 78 were right hemiplegics with aphasia (mean age 63.3, standard deviation [S. D.] = 12.8); 58 were right and left hemiplegic dysarthrics (mean age 61.3, S. D. = 13); and 17 were patients with multiple sclerosis (mean age 42.8, S. D. = 9.6). The total sample mean age was 60.2 years with a standard deviation of 14.8 years.

When the total data were organized it was found that only four of the total of 153 patients had received a "3" rating in physical therapy (wheelchair independent, a rare rating for hemiplegics and multiple sclerosis patients). Patients then were regrouped into two general improvement groups in speech and into two groups representing level of physical independence. Patients were grouped in this manner: 31 patients made no or slight improvement in speech and remained completely dependent in bed or in a wheelchair; only eight patients made good — or excellent improvement in speech who remained physically dependent; 52 patients made no or only slight speech improvement but became wholly independent in physical therapy; 58 patients made good or excellent speech progress and became wholly independent. A 2 x 2 contingency table yielded a significant χ^2 or chi square of 13.21 (significant at .001) indicating that the variations in number within the four cells were not chance variations. Specifically, there was a significantly greater number of patients making poor progress in both speech and physical therapy than patients doing well in speech but poorly in physical therapy. Of the 39 patients remaining dependent physically, approximately 80 per cent of them (31 cases) made little or no progress in speech. Ambulation status was achieved by 74 per cent of all patients (110 cases) and of this number 52 made little or no progress in speech while 58 made good or excellent speech progress. When the data were treated separately for the 78 aphasics, 58 dysarthrics and 17 multiple sclerosis patients, the relationship found for the sample as a whole did not change significantly. That is, patients who made poor physical progress 80 per cent of the time also did poorly in speech therapy.

Discussion and Summary

Patients who are so involved physically and psychologically that ambulation training is not possible, most of the time will not benefit from speech therapy. Among those patients who do well in physical therapy there is an approximate 50 per cent expectancy that improvement in speech will occur. No significant relationship was found between those patients who did well in physical therapy to the progress they made in speech therapy. Except for those hemiplegic and

Table 1: Ratings of 153 Patients After Receiving Both Speech Therapy and Physical Therapy

Type of Patient	Improvement After Speech Therapy	Status After Physical Therapy		CHI Square
		Bed-Wheelchair	Ambulatory	
Aphasics	None - Little	14	29	
(N = 78)	Good - Excellent	2	33	
Dysarthrics-CVA	None - Little	14	20	
(N = 58)	Good - Excellent	4	20	
Dysarthrics-MS	None - Little	7	4	
(N = 17)	Good - Excellent	2	4	
Total	None - Little	31	52	
(N = 149*)	Good - Excellent	8	58	$X^2 = 13.21$**

*Total of 153 minus four patients with "3" ratings, deleted to provide dichotomy between two groups.
**Significant at .001, based on 4 totals, d.f. = 3.

multiple sclerosis patients who do poorly in physical therapy, a prognostic index for speech improvement cannot realistically be based on the patient's present or predicted performance in physical therapy.

For the majority of hemiplegics and multiple sclerosis patients who improved during physical therapy (74 per cent in this study), no significant relationship was found between progress in speech therapy and progress in physical therapy.

There appear to be several implications from this study for the referral and selection of patients for speech therapy. For example, those patients who are physically or psychologically too involved to profit from physical therapy are usually too involved to make progress in speech therapy. This finding is consistent with the clinical experience of many speech pathologists, who often find after an early evaluation of the patient that he is not ready for therapy; however, the early evaluation of these patients is frequently a necessity in planning the management of the patient with the family and the staff. Another implication from these data is that among the large population of physically improving hemiplegic and multiple sclerosis patients, it is not possible to predict by physical status alone how well a patient will do in speech therapy. In this study, those patients who did well in physical therapy almost 50 per cent of the time made no progress in speech therapy.

Prognosis for speech recovery appears dependent on a thorough diagnostic evaluation of present language/speech functions related to the patient's former capacities and interests. Those accepted for therapy may require three or four hours daily of speech/language retraining if significant progress is to be achieved. More realistic evaluation of patients will permit acceptance for intensive therapy those few patients who, after testing, present an excellent prognosis, eliminating those patients who because of the severity of their disorders are not physically, intellectually, or psychologically ready for intensive speech therapy. Many right hemiplegics will, for example, become independent in ambulation and self-care after physical and occupational therapy, but continue to have global aphasia, with no possibility of benefit from speech therapy; some spontaneous return of language functions would be necessary before the patient could participate in aphasia rehabilitation.

While a significant relationship was found between absence of progress in both speech and physical therapies, there was only a chance relationship between progress in physical therapy to similar progress in speech therapy.

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Information relative to securing reprints of this study may be had by checking the Reader Service column on page iv of this issue.

Standard Routine and Procedure to Establish Uniformity in Clinical Electromyography

Karl H. Haase, M.D.
Los Angeles

● The electromyogram is as essential to the physiatrist as the electrocardiogram is to the cardiologist. In order that electromyography achieve its proper place as a generally accepted diagnostic aid, standardization of the technic for examination is necessary. The method of examination which the author has evolved as a result of more than 8,000 examinations is presented. Electromyography is a dynamic examination which should be done only by a trained physician. In interpreting the results, the primary criterion for denervation should be the fibrillation of denervation voltage. The positive denervation sharp wave should also be considered as one of the criteria of denervation. The author also describes and explains myotonic voltages and dystrophic activity. The written electromyographic report should include the muscles examined with their peripheral nerve and root innervation. There should be a report of pathology found in each muscle examined. If there is evidence of denervation present, the level of the lesion should be indicated. There should be a statement as to whether the lesion is partial or complete. When indicated, a statement should be made as to the prognosis and as to the necessity for serial examinations.

The clinical application of electromyography has been in existence approximately 16 years. During this time, it has become a relatively well accepted procedure in some areas, and also an integral part of a thorough medical work-up when indicated. Insofar as the practice of physical medicine and rehabilitation is concerned, it is as essential to the physiatrist as the electrocardiogram is to the cardiologist.

The present-day status of the electromyogram can be compared to that of the electrocardiogram approximately 25 years ago. At that time, there was no standardization of electrocardiogram as to leads, technics, etc. With standardization it went on to achieve its present highly important place in clinical and research cardiology. The uniformity of data could rapidly be correlated and utilized, and this fact has been largely responsible for our rapid advancement and understanding of cardiovascular disease. The electromyogram, too, is now ready for standardization and when it is, our knowledge of neuromuscular disorders will be more rapidly advanced. Many of the papers published on electromyography in the past should be repeated under the proposed standard conditions as for various reasons the early technics could not always result in valid findings.

From the view-point of the medical-legal application of electromyography alone, it is of paramount importance that standardization be set up so that some of the present courtroom procedures regarding electromyograms can be done away with, and justice truly be served with this useful and highly important objective examination.

There must always be a beginning and an appropriate time for standardization of routine and equipment in any procedure of medicine. This paper should accomplish that fact for electromyography, but even more so the presentation should stimulate and produce the necessary team approach by all electromyographers to eventually standardize the procedure as was done with electrocardiography. The correlation of electromyography with electric testing, conduction velocity studies and quantative excitability studies are essential to give the most valuable and complete standard routine in electrodiagnosis. The remainder of the paper will deal with the standardized electromyographic technics used at the Wadsworth General Medical and Surgical Hospital at the Veterans Administration Center, Los Angeles, Calif. This routine has been evolved and based on an eight year period of experience and a yearly evaluation of some 500 to 600 electromyograms. (These figures represent the number of patients; there is an average of two extremities and one group of paraspinous muscles done on each patient.)

Equipment

The basic requirements for clinical electromyographic instrumentation will not be discussed in detail. It is felt that the machines that are now available commercially are more than adequate to do the finest type of electromyography.

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Chief, Physical Medicine and Rehabilitation, VA Center; Assistant Clinical Professor of Physical Medicine and Rehabilitation, UCLA Medical Center, Los Angeles.

Standardization should be discussed with regard to the terminal type of equipment used. This includes the cable and types of electrodes. The most suitable cable is the three-electrode type (*A* in fig. 1), which eliminates all forms of surface electrodes and allows the recording of voltages directly from the muscle being examined with no base line disturbance. (It should be noted that many electromyographers find surface electrodes satisfactory for the ground and negative electrodes, when a needle is used for the recording electrode.)

At the present time, there is no place in clinical electromyography for use of surface electrodes of any type. The technical difficulty encountered in the proper interpretation of voltages when surface electrodes are used, due to base line disturbances, makes accurate readings highly unlikely. This is particularly true when examining the small muscles of the hand or the paraspinous musculature.

There are two types of recording electrodes, both of which are satisfactory and will give similar results when used interchangeably on the same muscle. They are: (1) Unipolar electrode (fig. 2 and *B* in fig. 1) and (2) Bipolar electrode (*C* in fig. 1). The unipolar needle electrode is the one of choice as it is cheaper and smaller in diameter, thus less painful than the bipolar. The unipolar is a solid needle entirely covered by plastic insulating material except for its very tip. The bipolar needle consists of a hollow needle with a single wire inside which touches only the muscle being examined. The unipolar recording needle can be attached to the cable outlet by two methods, both utilizing the alligator type clamp. The first alligator clamp (*D* in fig. 1) has a length of wire attached to it, this allows greater flexibility and mobility in handling the recording needle. The second alligator clamp (*E* in fig. 1) has a phone tip on the other end which inserts directly into the cable outlet. The bare wire end of the unipolar needle electrode is clamped in the jaws of the "alligator" clamp and is then ready for use (fig. 2). The bipolar electrode has two phone tips which can be inserted directly into the plus and minus sockets in the cable outlets. When the unipolar needle is being used, an additional two needle electrodes also are attached to the cable; one being the negative electrode and the other being the ground (fig. 2). The usual type of electroencephalogram needle electrode is adequate; though somewhat fragile and therefore difficult to handle. However, in a large institution where many examinations are done and a ready supply of autoclaved hypodermic needles (size 26, ½ inch long) are available, the banana plug terminals can be used (*F* in fig. 1). The hypodermic needle will fit over the banana plug and these can be readily inserted in the area to be examined (*G* in fig. 1). This is a marked advantage because these needles then are not only adequately sterilized by means of the autoclave, but also are always well sharpened, which means less pain for the patient.

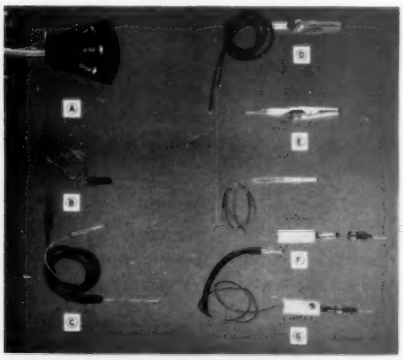

Fig. 1 — Cable Outlets and Electrodes. *A*. Cable outlet. *B*. Unipolar electrode. *C*. Bipolar electrode. *D*. Alligator clamp electrode and wire. *E*. Alligator clamp electrode. *F*. Banana plug electrode without needle attachment. *G*. Banana plug electrode with needle attachment.

Fig. 2 — Electrode placement for examination of a single muscle.

If the bipolar recording needle is used, then it is best that an additional needle electrode as described (*G* in fig. 1), be utilized as the ground electrode. It is also proposed that the recording needle be attached to the positive electrode (fig. 2); then the first major deflection would always be positive in the fibrillation of denervation voltages and positive denervation sharp waves. It is extremely important that this be done so that all pictures and permanent recordings will appear similar to everyone doing electromyography. This would eliminate the present confusion that exists because of the use of the negative electrode as the recording electrode.

The Examiner

This examination should be done only by a trained medical doctor. The individual doing the examination must have the necessary specialized training in clinical medicine in order to properly interpret and then correlate his electromyogram findings with those of the clinical picture. It should, therefore, never be done by a lesser trained individual (i.e. nurse, technician, therapist, etc.). This is a dynamic examination and relaxation of the patient is of primary importance for a valid reading. It is only the actual person doing the examination who can adequately evaluate whether or not the patient is relaxed. Therefore, this examination cannot be done by a technician and recorded on tape, and then read at the convenience of the physician. The actual interpretation of the electromyogram must be done by the examiner during the examination. Such a procedure would immediately render the examination worthless and might well be left undone rather than mislead the referring clinician.

It is extremely important to prepare the patient psychologically for this examination, as the insertion of the needle into the muscle does cause some pain. This again can only really be done adequately by the physician who is to do the examination. Many types of sedation have been tried but none have been of too much value. However, the manner in which the electromyographer handles the patient by keeping up a continuous line of chatter and humor will be of great value as it helps relax the patient and makes the examination not too unpleasant.

This technic for patient relaxation, when properly utilized, could be considered to be an extremely light hypnotic state, accomplished by suggestion and diversion of attention away from the examination at hand.

Adequate relaxation and cooperation of the patient is the single most important factor for a satisfactory examination.

Examination of Individual Muscles

Each muscle should be adequately examined, both in terms of number of samples and area examined. Generally, this consists of sampling three different areas and taking a minimum of five readings in each area. The recording electrode should be placed directly into the muscle, perpendicular to the skin. The needle is inserted through the skin with firmness but gentleness, and the more rapidly this can be done the less discomfort for the patient. The other two needle electrodes should be placed over the same muscle with the needles penetrating the skin. It has been found that when all electrodes are inserted in the same muscle (fig. 2) all base line and background disturbances are eliminated in a relaxed patient.

If the muscle to be examined has a linear shape, then it should be divided in thirds and the approximate center of each third examined (*A* in fig. 3). It has been found that in linear muscles innervated by more than one root, the proximal half is primarily innervated by the lower numbered root, and the distal half by the other (higher numbered root, i.e. anterior tibial muscle proximal half, fourth lumbar nerve, distal half, fifth lumbar nerve).

If the muscle to be examined is a broad muscle (i.e. deltoid or quadriceps), it should be divided into thirds and the center of each third examined (*B* in fig. 3).

After the recording needle electrode has been placed into the muscle, at least five readings should be taken in this area. The first reading can be taken with the

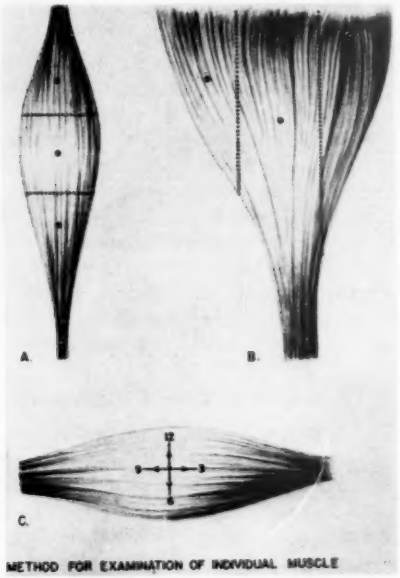

Fig. 3 — A. Example of linear muscle. B. Example of broad muscle. C. Direction of recording needle within the muscle.

needle in the original perpendicular position. The other four readings are taken by moving needle obliquely in relation to the skin surface toward the 3, 6, 9, and 12 positions on the clock. A reading is taken from each of these positions (*C* in fig. 3). Thus, a minimum of 15 readings per muscle has been accomplished, in a complete and systematic manner. The chance then of overlooking or missing pathology is eliminated for all practical purposes.

Examination of Upper Extremities

There should be a routine minimal number of muscles examined, in the upper extremities and shoulder girdle. This usually gives adequate coverage of the entire innervation. The suggested muscles with appropriate peripheral nerves and primary segmental distribution are shown in table 1. It should be emphasized that it is possible to examine almost any individual muscle of the upper extremity and shoulder girdle by electromyography. The ability and skill necessary to accomplish this type of detailed and extensive examination depends directly upon the examiner's knowledge of anatomy and kinesiology. Usually, in brachial plexus injuries for example, a more extensive examination than the minimum number of muscles must be done in order that the proper level of the lesion can be determined. The proper level of the lesion again can only be determined if the examiner has sufficient knowledge and background in neuroanatomy and kinesiology. The knowledge of kinesiology is stressed because it is only by proper muscle testing with the recording needle in place that the examiner can determine which muscle he is examining.

Examination of Lower Extremities

There also should be a routine examination for the lower extremities, which should include the following muscles or muscle groups (table 2).

Here, again, on many occasions a more detailed examination is necessary. The previous comments involving the

Table 1: Minimal Muscle Examination Upper Extremity

Muscle	P. Nerve	Root
Supraspinatus	Suprascapular	C 5, 6
Infraspinatus	Suprascapular	C 5, 6
Deltoid	Axillary	C 5, 6
Triceps	Radial	Mainly C 7
Biceps	Musculocutaneous	C 5, 6
Brachioradialis	Radial	C 5, 6
1st Dorsal Interosseus	Ulnar	C 8, T 1
Abductor Digiti Quinti	Ulnar	C 8, T 1
Opponens Pollicis	Median	C 8, T 1
Abductor Pollicis Brevis	Median	C 8, T 1

Table 2: Minimal Muscle Examination Lower Extremity

Muscle	P. Nerve	Root
Quadriceps	Femoral	L 2, 3, 4
Ant. Tibial	Common Peroneal	L 4, L 5
Peroneal Group	Common Peroneal	L 5, S 1
Lat. Head Gastrocnemius	Post. Tibial	S 1
Med. Head Gastrocnemius	Post. Tibial	S 2

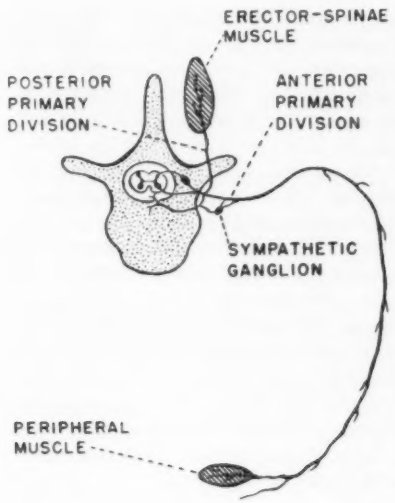

Fig. 4 — The anatomic basis of localization by electromyography.

examination of the upper extremities and shoulder girdle (regarding detailed examination and localization of level) apply to the lower extremity as well.

Examination of Paraspinous Muscles

The examination of the paraspinous muscles is absolutely essential in order to place a lesion at a root level. If denervation is found in both the anterior and posterior primary divisions of the peripheral nerve, then by deductive reasoning the lesion must be at the root level or proximal to root level (i.e. root, cord, or anterior horn cells, fig. 4). No electromyographer can truthfully report involvement of a peripheral nerve at a root level if he has failed to examine the erector spinae muscles or failed to find involvement in the erector spinae muscles. The myotome must be completed in toto (including anterior and posterior primary divisions) to indicate root involvement. If the patient has had previous spinal surgery, findings of denervation in the paraspinous muscles are of no diagnostic value. This fact is fairly obvious because it is impossible to avoid minor injury to some branch of the posterior primary division of the nerve during surgery. In any such case, peripheral localization would then be permissible to conclude a root lesion. However, it should also be remembered that in examining patients who have had previous spinal surgery, if denervation is found peripherally there is no way to determine if these findings are recent or old. The electromyogram in these instances cannot determine the time of onset. The usual reason given by many electromyographers for not examining the paraspinous muscles is that they are unable to relax the patient sufficiently to secure a good base line. There should, however, be no difficulty in examining these muscles properly if one uses the needle electrode method and the patient is properly postured so he can relax the muscles.

The position which gives the best relaxation of the erector spinae muscles in the lumbosacral and lower thoracic area is shown in figure 5. Figure 6 shows the position which gives the best relaxation of the erector spinae muscles in the upper thoracic and cervical area. In both instances only the left erector spinae muscles will be relaxed while the patient is lying on his right side. The position must be reversed in order to examine the right erector spinae muscles under the proper degree of relaxation.

Examination of Additional Muscles

It should be noted that the examination of muscles of the face, neck, thorax, pharynx, and pelvis can be adequately carried out when indicated. Almost all muscles are then available for electromyographic examination. The tongue presents a particular problem because of the difficulty encountered in achieving proper relaxation. However, if the tongue is anesthetized with a topical anesthetic prior to needle insertion, there is a better than 50 per cent chance for an adequate base line and successful examination. The indifferent electrode needles (*G* in fig. 1 negative and ground), should be placed in the neck on the same side that the tongue is being examined or as close to base of tongue as possible.

If the recording needle electrode must pass through mucous membrane to reach the muscle to be examined, the use of a topical anesthetic agent on the mucosa facilitates the examination and insures a good base line from a comfortable and cooperative patient.

Criteria for Denervation

The basis for present day clinical electromyography is the fibrillation of denervation voltages found in denervated muscle. This voltage then should be the primary determining criterion for the presence of denervation. The positive denervation sharp wave also should be considered one of the criteria of denervation. An interpretation of denervation should not be based on any other findings (fig. 7, upper left figures). It should be pointed out that the positive denervation sharp wave is in actuality the electromyographer's best friend. This is true because they are so readily provoked and discovered. This alerts the examiner to the presence of possible denervation and then he can easily find the fibrillation of denervation voltages. These can always be found if positive denervation sharp waves are present. There are two types of fibrillation voltages; one is mechanically induced by the insertion of the needle electrode; the other is spontaneous induced fibrillation which will occur without irritation by the needle. The fibrillation voltages are usually from 10 to 300 microvolts with a duration of one to two milliseconds and frequency of 3 to 30 per second. They are absolutely irregular in rhythm.

The auditory component is the most characteristic of all, sounding as if rain

Fig. 5 — Position for examination of lumbosacral and lower thoracic paraspinal muscles.

Fig. 6 — Position for examination of upper thoracic and cervical paraspinous muscles.

drops were falling on a tin roof, a few at a time. The positive denervation sharp wave has a great variability in voltage. Its duration may be up to 100 milliseconds. It is diphasic with a frequency of two to 100 per second, its sound being that of a dull, loud thumping noise.

Criteria for Muscle Degeneration and Regeneration

(Fig. 7, Upper Right Figures)

The demonstration of myotonic voltages and dystrophic activity by electromyography signifies that there is present in the muscles a process of degeneration or regeneration of muscle tissue. Myotonic voltages are generally of very high frequency, rapid duration, and have a distinct sound which can be likened to that of a diving airplane. These myotonic voltages are easily precipitated by needle insertion.

Dystrophic voltages occur in primary muscle disorders because there is a loss in the number of muscle fibers per motor unit. If a sufficient number of these muscle fibers have been replaced by fibrous connective tissue, then upon voluntary contraction, there is seen electromyographically "fibrillation-like potentials." It is termed fibrillation-like because the voltages appear similar to fibrillation voltages, but these occur on voluntary contractions only and are regular in rhythm (fibrillation voltages are involuntary and irregular).

Some of the other voltages observed in electromyography, such as the normal motor unit, polyphasic motor unit, nascent motor unit, giant motor unit, and negative nerve fibers are also illustrated (fig. 7, lower half). These are well described in the medical literature.

A great variation in size of normal motor units can be demonstrated within the same muscle, or different muscles in normal individuals. This fact makes interpretation of the size of normal motor units for clinical application unsatisfac-

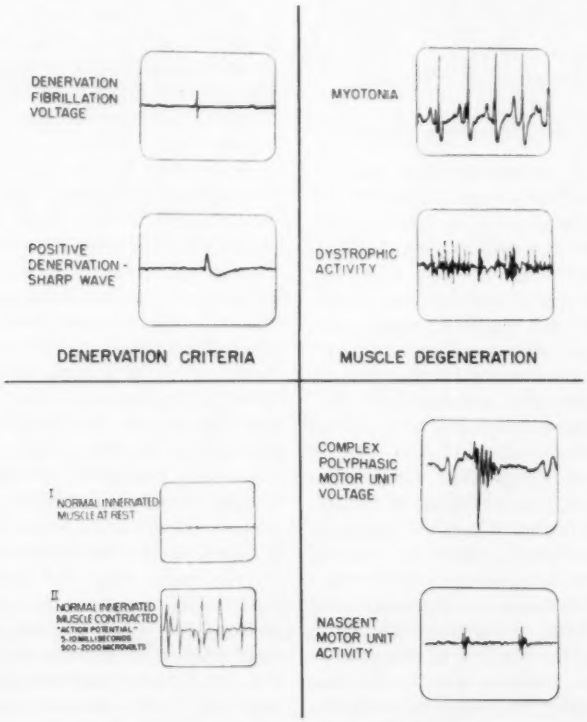

Fig. 7 — Electromyographic voltage.

tory as an endpoint could never be established.

The measurement of the amplitude and duration of the various voltages can very readily be dispensed with because these findings are of no practical clinical importance. These merely make the examination more time-consuming, laborious, and confusing. Therefore, there is no reason at this time to place any clinical significance on various sizes of motor units in the same muscles, or in different muscle groups. Most involuntary motor units observed during electromyography are found in patients who have pure upper motor neuron pathology and no lower motor neuron involvement.

Fasciculation voltages are of no clinical significance unless accompanied by the criteria for denervation.

Artifacts occur rather frequently during electromyographic examination. It is suggested that all these artifacts be disregarded for practical and diagnostic purposes in clinical electromyography. These should be studied further by research investigators. The electromyographer should only use and apply the presently known and proven criteria for clinical interpretation and diagnosis.

Prognosis of Denervation Lesions

In cases of peripheral nerve injuries, it is possible electromyographically to determine if regeneration is taking place. It should be very obvious that even in the best hands this can only be determined by frequent serial examinations.

There has been much discussion concerning the polyphasic and nascent motor units as aids in determining if regeneration is taking place. Experience has shown that regeneration can be suspected on the initial examination if there is a preponderance of positive denervation sharp waves and a minimum of fibrillation voltages found. When the regeneration of a peripheral nerve is followed serially by electromyography from onset to complete regeneration, the number of fibrillation voltages decrease steadily in proportion to the number of positive denervation sharp waves. This is also true in a peripheral nerve which at onset has no voluntary components. This change in ratio, increase of positive denervation sharp waves, and decrease in number of fibrillations of denervation occur in advance of the appearance of any voluntary components. This then is the first sign that the nerve is regenerating. Following this an occasional nascent motor unit may be observed and then an occasional sustained polyphasic motor unit.

Later on in the course of regeneration there continues to be a decrease in the fibrillation voltages and increase in the positive denervation sharp waves and continued increase in the number of voluntary motor units; usually polyphasic early and then a mixture of polyphasic and normal motor units until there is complete return with no criteria of denervation remaining.

Interpretation of the Electromyogram

It has already been pointed out that only the electromyographer at the time of the examination can make a valid reading, as he is the only individual who knows if the patient is properly relaxed. Several individual voluntary motor units in each area should be examined. The fibrillation voltages and positive sharp waves should only be accepted as being present when they occur in the presence of an absolute flat, normal base line (fig. 7, *1* in lower left). Also, upon immediate movement of needle there are insertion potentials which should not be considered as pathologic. No readings of fibrillation or positive denervation sharp wave activity should be made while the fingers are still touching the recording needle; there should be a pause of a two count after the fingers are off the needle before one attempts to determine if fibrillation voltages or positive denervation sharp waves are present. This added caution eliminates many misleading insertion potentials. It should be noted that the human ear is far less subject to error of interpretation than the human eye in electromyography. It is highly recommended that if there is any doubt, make your final interpretation on the basis of the sound component and not by the visual one. If the examiner feels that for any reason the fibrillation potentials are

present in a partial lesion but not being brought out, the best method for producing fibrillation of denervation voltages is exercise of the involved muscle or group of muscles in that area. This certainly has a far greater stimulating effect on the fibrillation of denervated muscle fibers than electrical stimulation, heat or prostigmine injections.

Myotonic discharges have always been associated with primary muscle disorders and is one of the criteria necessary to establish muscle regeneration or degeneration. From time to time, "myotonic-like" discharges are seen in cases of clear-cut peripheral nerve injuries. In addition, there are ample findings of denervation present (fibrillation potentials and positive denervation sharp waves). However, these muscles appear to be abnormally hyperirritable and because of this there occur bursts of positive denervation sharp waves which sound like myotonic discharges but do not look exactly like typical myotonic potentials. The positive denervation sharp wave in the negative phase (fig. 7, upper left) appears concave and looks like an inverted "T" wave on the electrocardiogram. The myotonic voltage in negative phase (fig. 7, upper right) appears coved and looks like a coved "T" wave on the electrocardiogram. The appearance of these "myotonic-like" voltages then should not interfere with the conclusion that the primary and only pathology is one of denervation.

In examining for dystrophic activity, it is best to utilize the most atrophic muscles and those muscles which can be contracted individually without contracting a large number of surrounding muscles. This then allows one to find more easily these depleted motor units. Many times it is impossible to demonstrate dystrophic activity because any minimal muscle contraction will precipitate myotonic discharges which then mask all other findings.

It should be repeated again that if partial denervation exists, the positive denervation sharp waves and fibrillation of denervation voltages are always present and therefore they can very easily and readily be demonstrated. It does not involve a great deal of time, a large number of areas, or a large number of needle punctures to find them. Without further explanation if it takes 10, 15, or 20 minutes for the examiner to find what he thinks are a few denervation potentials, then they probably are not present.

Electromyographic Report

The electromyographic reports should reflect a purely objective examination on the part of the electromyographer. It is essential that this report be kept brief and simple but complete enough not to be misleading. Electromyographic reports can be divided into two distinct types; one, the permanent record which consists of camera photographs and tape recordings. This type of report is not necessary in clinical electromyography, and this conclusion is based on the fact that it is a dynamic examination and the findings are only valid and interpretable to the electromyographer when he is doing the examination. As a matter of fact, fibrillation voltages are generally similar and do not vary from muscle to muscle or person to person. Therefore, a photograph or recording of a fibrillation voltage from one individual or muscle is identical to that from any other individual or muscle. These same facts also apply to positive denervation sharp waves. On this basis these permanent recordings and pictures are not needed for hospital or office records and do not belong in a court of law to take the place of the written report of the electromyographer or his expert testimony from the written report.

The prime use of these permanent records is for teaching and research.

The second report is the written report. This report should include the muscles examined with their peripheral nerve and root innervation. There should be a report of pathology found in each muscle examined. If there is evidence of denervation present, the level of the lesion should be indicated. There should be a statement as to whether the lesion is partial or complete. The degree of severity should also be noted. This can easily be evaluated on the ratio of fibrillation voltages to positive denervation

sharp waves present and also the number of voluntary components found. When indicated, a statement should be made as to the prognosis and recommendation as to necessity for serial examination. Recommendations can be made for additional examinations of type available in a physical medicine and rehabilitation department (electrical testing, manual muscle test, sweat test, etc.). The examiner may feel free to make a statement regarding the possible clinical entities which would be compatible with these findings. The diagnostic impression must be clear, and concise, so it can be easily understood by the referring physician.

Example: *Diagnostic Impression*: Abnormal Electromyogram, evidence of lower motor neuron involvement, at root level L-5, left, partial, mild.

Summary and Conclusions

A routine for the standardization of the electromyographic examination has been presented. A uniformity of the clinical electromyographic examination will in the near future firmly establish electromyography in its proper, highly important place in clinical medicine. It must be remembered that electromyography is not the ultimate in electrodiagnosis, but a standard routine should also include conduction velocity and quantitative excitability studies. Standardization of technic and procedure will hasten progress in our understanding of neuromuscular function and disorders through future valid correlative clinical research.

Information relative to securing reprints of this study may be had by checking the Reader Service column on page iv of this issue.

Few can be induced to labor exclusively for posterity: and none will do it enthusiastically. Posterity has done nothing for us; and, theorize on it as we may, practically we should do very little for it, unless we are made to think we are at the same time doing something for ourselves.

— ABRAHAM LINCOLN

Respiratory Status and Metabolic Requirement As Determined by Measurement of Carbon Dioxide Production

H. J. Ralston, Ph.D.
Gregory Bard, M.D.
and
Carrie E. Chapman, M.D.
San Francisco

● Several investigators, most recently Ford and Hellerstein (J. Appl. Physiol. 14:891, 1959), have examined the relationship between pulmonary ventilation and oxygen consumption in normal human subjects, with a view to using ventilation alone as an adequate index of energy expenditure. As shown by Margaria, Taglietti, and Agostoni (J. Appl. Physiol. 11:235, 1957), the relationship between ventilation and carbon dioxide production may be even more useful, since it provides information regarding the respiratory dead space and the alveolar carbon dioxide tension as well as energy expenditure. The present report describes such studies on subjects with motor impairment. It is shown that ambulatory hemiplegic patients are characterized by a very small dead space, low alveolar carbon dioxide, and elevated ventilation for a given energy expenditure, compared with normal subjects. The respiratory status of certain other selected patients is also analyzed with the same method.

A number of investigators have noted the approximately linear relationship between pulmonary ventilation and oxygen consumption in normal human subjects, during moderate exercise, for oxygen consumptions up to about two liters per minute. Study of this relationship suggests the possibility of using pulmonary ventilation alone as an index of metabolic requirement, and equations relating these functions have been published. We shall describe in the first part of this paper some recent attempts to express quantitatively, in terms of ventilation, the metabolic rate during exercise and offer some additional data and equations based on our own and others' work.

The findings of Margaria and coworkers,[1] independently confirmed by us, indicate that it might be more profitable to relate ventilation to carbon dioxide production, rather than to oxygen consumption, for better predictability of energy expenditure. Also, studies of ventilation as related to carbon dioxide production yield such important information as values for pulmonary dead space and alveolar carbon dioxide tension. Consideration of ventilation-carbon dioxide curves will constitute the second part of this paper.

Relationship Between Ventilation and Metabolic Rate

For conditions of moderate exercise, corresponding to oxygen consumption of up to two to two and one-half liters per minute, the relationship between pulmonary ventilation and oxygen consumption may be approximately represented by an equation of the form:

$$\dot{V} = a\dot{V}o_2 + b$$

where $\dot{V}$ is pulmonary ventilation in liters per minute, $\dot{V}o_2$ is oxygen consumption in liters per minute, and a and b are constants. Since, for stabilized conditions, the oxygen consumption is directly proportional to the metabolic rate, the above equation may be transposed and written:

$$\dot{E} = a'\dot{V} - b'$$

where $\dot{E}$ is energy expenditure in kilocalories per minute, $\dot{V}$ is the ventilation in liters per minute, measured at body temperature, pressure, saturated conditions, and a' and b' are constants.

The quantities b and b' are measures of pulmonary dead space plus dead space in the external measuring apparatus. They are therefore subject to unpredictable variation unless correction is made for the external dead space. The values a and a' are the slopes of the corresponding straight lines and represent a fairly constant relationship, which

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From the Biomechanics Laboratory and the Department of Physical Medicine and Rehabilitation, University of California School of Medicine, San Francisco, and the Physical Medicine and Rehabilitation Service, Veterans Administration Hospital, Oakland, Calif.

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various investigators have examined (see table 1).

Table 1: Mean Values of a' as Determined in Various Studies (Male Subjects, Aged 17-66 Years)

Study	No. of Subjects	Mean Value of a'
Margaria (1938)[2]	4	0.20
Silverman et al. (1951)[3]	11	0.216*
Durnin and Edwards (1955)[4] ..	34	0.235
Sartorelli (1956)[5]	10	0.204
	14	0.209
Ford and Hellerstein (1959)[7] ..	52	0.173
Present study (1960)	10	0.226

*Calculated by us.

The relatively low value of a' obtained by Ford and Hellerstein[7] was for industrial workers and was at predominantly lower values of oxygen consumption. The relatively high value obtained by Durnin and Edwards[4] was for subjects in a field study and was at predominantly higher values of oxygen consumption.

The weighted mean of the values of a' in the table is 0.203. The ventilation-energy equation may therefore be written:

$$\dot{E} = 0.203\dot{V} - b'$$

As will be evident below, the average value for pulmonary dead space may be derived from the ventilation-carbon dioxide relationship. For 10 normal subjects, we have found the average value of b' to be $0.460 + 3.29V_{DX}$, where V_{DX} is the external dead space in liters.

The standard error of $\dot{E}$, where it can be determined, is not far from 0.5 kcal./min.

With use of the equation

$$\dot{E} = 0.203\dot{V} - 0.460 - 3.29V_{DX}$$

for predicting the metabolic rate of 10 subjects walking in the laboratory (subjects were not used in the previous evaluation of the various coefficients), an average error of 21 per cent resulted, the true value always being underestimated. The main errors occur at conditions of rest or low levels of activity. However, an error of 25 per cent may occur even at moderate levels of activity.

Using the value 0.226 for a', as found by us, predictability during walking in the laboratory is much better, the average error being 11 per cent. Here, again, the largest errors occur at conditions of rest or very low levels of activity.

We are of the opinion that the value of a' may prove to depend on the nature of the exercise under consideration. The ratio $\dot{E}/\dot{V}$ is a kind of measure of pulmonary "efficiency," and seems to run lower for industrial conditions than for those in the laboratory.

Relationship Between Ventilation and Carbon Dioxide Production

It has been shown by Margaria et al.[1] and independently established by us that, on well-known physiologic grounds, there should be a linear relationship between the tidal volume and the carbon dioxide production per breath, as follows:

$$V_T = mV_{CO_2} + V_D + V_{DX}$$

where V_T is the tidal volume, V_{CO_2} is the carbon dioxide production per breath, V_D is the pulmonary dead space, V_{DX} is the external dead space, and m is a constant. $V_D + V_{DX}$ is the intercept on the V_T axis. It will be noted that determination of V_T and V_{CO_2} requires measurement of the respiratory rate, but this ordinarily does not present a serious problem.

The significance of the slope m is that it is a measure of the alveolar carbon dioxide tension. The ratio $\frac{760 - 47}{m}$ yields the value of the carbon dioxide tension in dry alveolar air at standard pressure and body temperature. This value tends to be relatively constant under conditions of rest and moderate stabilized activity, the commonly accepted figure being 37 mm. Hg. The expected value of m is therefore

$$\frac{713}{37}, \text{ or } 19.3.$$

In their subjects, Margaria et al.[1] found values of $m = 19.23$ and 18.99. We have calculated from the data of Silverman et al.[3] the average value of m for their 11 young male subjects riding a bicycle ergometer; this value is 19.3. We have determined the value of m in 10 normal

male subjects (aged 17-54) walking in the laboratory, the average value being 18.6, with a standard deviation of only 0.37. We may conclude, therefore, that the value 19 for m may be taken as a nearly constant index of normal relationship between tidal volume and carbon dioxide production per breath and, therefore, between tidal volume and metabolic rate under conditions of rest or moderate exercise.

The value of V_T also includes the quantities V_D and V_{DX}. We have found in our 10 subjects a value of $V_D = 0.169$ liter, with a standard deviation of 0.045. This value is in excellent agreement with those found by Margaria et al.[1] and is in the range commonly accepted as normal.

We have examined the respiratory and metabolic status of six male hemiplegic patients (aged 54-71), all with a history of cardiovascular disease, and 12 male lower extremity amputees (aged 49-73), many of whom have a history of cardiovascular disease. The patients walked at various rates on a measured track in the laboratory.

The hemiplegic patients had the following characteristics: a high value of m, averaging 22.93, a low value of V_D, averaging 104 ml., a relatively small tidal volume compared with that of normal subjects, and a relatively high respiratory rate. The physiologic picture emerges of impaired respiratory efficiency, with rapid shallow breathing and abnormally high ventilation for a given metabolic demand. The value of the alveolar carbon dioxide tension, calculated from the ratio $\frac{713}{22.93}$, is only 31 mm. Hg.

In the light of our present knowledge it is not easy to interpret the meaning of the low alveolar carbon dioxide tension coupled with a small dead space, but we incline to regard it as indicating hyperventilation associated with turbulent air movement within the pulmonary passages.

The differences noted between hemiplegic patients and normal subjects might possibly be due to the large average difference in age, as well as the motor impairment in the former group. In this respect, the amputee subjects constitute a control group as far as age is concerned. Here, the average value of m, 25.64, is significantly different from that of both normal and hemiplegic subjects. The value for dead space is not significantly different from that in either of the other groups, and the tidal volumes and respiratory rates, for a given metabolic demand, tend to fall between those for normal and hemiplegic subjects.

To summarize, it may be said that measurement of pulmonary ventilation, respiratory rate, and carbon dioxide production provides information regarding the respiratory and metabolic status not so easily obtained from oxygen data. The relationship between tidal volume and carbon dioxide production per breath in the normal subject is less variable than that between ventilation and oxygen consumption, as would be expected from the close physiologic association of alveolar carbon dioxide tension and ventilation. The equation

$$V_T = 19V_{CO_2} + 0.169 + V_{DX}$$

or, by transposition,

$$V_{CO_2} = 0.0526V_T - 0.0089 - 0.0526V_{DX}$$

provides a means of estimating carbon dioxide production from measurements of ventilation and respiratory rate. The value of V_{CO_2} thus obtained may be used as an index of energy expenditure.

Weir[6] has shown that energy expenditure in kilocalories (E) is related to CO_2 production in liters (V_{CO_2}) by:

$$E = \frac{3.9V_{CO_2}}{R} + 1.1V_{CO_2}$$

where R is the respiratory quotient.

The average value of R in our normal subjects was 0.82, whence

$$E = \frac{3.9V_{CO_2}}{0.82} + 1.1V_{CO_2} = 5.9V_{CO_2}$$

Substituting:

$$E = 5.9(0.0526V_T - 0.0089 - 0.0526V_{DX})$$
$$= 0.310V_T - 0.0525 - 0.310V_{DX}$$

Energy expenditure in kcal./min. ($\dot{E}$) then will be:

$$\dot{E} = f(0.310V_T - 0.0525 - 0.310V_{DX})$$

where f is the respiratory rate. V_T is measured at standard conditions.

This equation aims to predict energy expenditure solely from measurements of pulmonary ventilation and respiratory rate. In a series of 17 normal male subjects, the equation has proved to be satisfactory for moderate degrees of exercise.

Predictability is within an average error of five per cent for oxygen consumptions in the range of 500 to 1,000 cc./min.

A mathematical treatment similar to that above may be used for handicapped subjects, provided suitable values of m, V_D, V_{Dx} and R are used.

Needless to say, such a relationship should be thoroughly tested, as in the recent study of Ford and Hellerstein[7] on metabolic rates of industrial workers, before being accepted as superior to ventilation-oxygen equations.

Summary

1. Various investigators have studied the mathematical relationship between pulmonary ventilation and oxygen consumption, but some errors of prediction are involved in their use.

2. Ventilation-carbon dioxide relationships may provide better predictability, and such relationships give additional information regarding respiratory status, including alveolar carbon dioxide tension and pulmonary dead space.

3. An equation, given above, relates tidal volume to carbon dioxide production per breath in normal subjects and should be tested as an estimate of metabolic requirement.

4. Values for pulmonary dead space and alveolar carbon dioxide tension, determined in hemiplegic patients by use of this equation, are relatively low compared with those of normal subjects. Geriatric amputees, many of whom had a history of cardiovascular disease, were found to have a lower value for alveolar carbon dioxide than either the normal subjects or the hemiplegics. Their dead space was within normal limits.

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Information relative to securing reprints of this study may be had by checking the Reader Service column on page iv of this issue.

Electromyographic Evaluation of the "Cross Exercise" Effect

Nicholas Panin, M.D.
Harold J. Lindenauer, M.D.
Andor A. Weiss, M.D.
and
Alfred Ebel, M.D.
New York

● Early observations by Scripture (1894) and Davis (1898) have given support to the theory of transfer effects of contralateral exercise, leading to the creation of the term "cross exercise." Subsequent investigations of Wissler and Richardson (1900), Slater-Hammel, Hellebrandt, Parish, Houtz, Walters and Partridge were done with the purpose of confirming the theory of cross exercise. An increase in strength in contralateral non-exercised muscles was found by these investigators when the biceps was exercised against increasing loads. Recent electromyographic studies by Gregg, et al, were presented as further evidence of the cross-effect. Some doubt about the validity of this concept has been expressed by Mueller. Rose, et al, demonstrated muscle atrophy in a lower limb immobilized by a cast in spite of exercises given to the contralateral lower extremity. A complete denial of cross exercise effects was expressed by Kruse and Mathews on the basis of careful clinical experiments. It was our aim to check the effect of exercise on distant muscles in the body by means of multi-channel electromyogram, using skin electrodes. The right biceps and the right quadriceps were exercised: (a) without resistance; (b) with increasing loads; and (c) isometrically. The EMG potentials in actively exercised muscles and in distant nonexercised muscles of the upper and lower extremities were recorded. The presence and nature of the potentials is discussed in relation to exercise value.

The effect of exercise upon distant unexercised muscles has been studied by many investigators. The earliest report is that of Scripture,[1] published in 1894, who studied these effects experimentally. He coined the term "cross education" for the effects produced upon distant muscles. Investigations by Davis[2] in 1898 gave support to the theory that transfer effects on unexercised muscles were due to "cross exercise." In 1900 Wissler and Richardson[3] demonstrated an increase in strength in contralateral unexercised muscles which they attributed to a diffusion of motor impulses to the unpracticed muscles. Walshe[4] in 1923 reported his studies on associated contralateral movements in spastic hemiplegics and came to the conclusion that these were, in effect, tonic postural reflexes evoked by powerful voluntary contraction on the contralateral side, requiring widespread synergic fixation. In 1947 Hellebrandt, Parrish and Houtz[5] questioned Scripture's original designation of the cross education[6] effect which presupposed that the unpracticed limb was unexercised. Using heavy unilateral resistance exercises, she and her co-workers were able to demonstrate an increase of strength in symmetric unexercised contralateral muscles. In their opinion the cross exercise effect was found to depend primarily upon the severity of the exercise rather than on the duration. Davis[7] studied the pattern of electrical activity in distant non-exercised muscles and concluded that the degree of activity varied with the severity of the exercise administered. He, furthermore, demonstrated presence of electrical activity not only in the contralateral limb, but in all three non-exercised limbs. In 1950, Slater-Hammel[8] showed that exercise of one upper extremity produced definite and positive improvement of strength in the contralateral non-exercised upper extremity. Walters[9] emphasized the clinical importance of cross education in immobilized non-functioning but normally innervated muscles. She concluded that the greatest effects were achieved by exercise with overload, and further stated that this type of exercise was equal in effect to direct exercise without resistance. Mueller[10] was unable to produce increase in strength in contralateral unexercised muscles when isometric exercises were used. He attributed the positive findings of Hellebrandt and others to the fact that in dynamic exercises, such as they used, there is an increase in cardiorespiratory function which af-

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Clinical Instructor, Rehabilitation Medicine, Albert Einstein College of Medicine; Assistant Chief, Physical Medicine and Rehabilitation Service, Veterans Administration Hospital, East Orange, N. J.

Assistant Clinical Professor, Rehabilitation Medicine, Albert Einstein College of Medicine; Chief, Spinal Cord Injury Section, Physical Medicine and Rehabilitation Service, VA Hospital, Bronx, N. Y.

Associate Clinical Professor, Rehabilitation Medicine, Albert Einstein College of Medicine; Assistant Chief, Physical Medicine and Rehabilitation Service, VA Hospital, Bronx, N. Y.

Associate Clinical Professor, Rehabilitation Medicine, Albert Einstein College of Medicine; Chief, Physical Medicine and Rehabilitation Service, VA Hospital, Bronx, N. Y.

fects the entire body including the non-exercised muscle. He also believed that frequent testing of the unexercised muscle would in itself act as a sufficient stimulus to produce an increase in strength. Based on his studies with isometric exercise he concluded that a contraction equal to 20 per cent of maximal strength was required to prevent atrophy of disuse. While exercise using 35 per cent of maximum strength resulted in an increase in muscle strength, daily exercise using two-thirds of maximum strength was found to be the optimal method of producing increase in muscle strength. Exercise of only six seconds' duration, given once a week, and using maximum strength, produced a gain in strength, although at a slower rate than did exercise performed on a daily basis. Rose[11] found a cross exercise effect in the contralateral non-exercised extremity when it was free to move. If the non-exercised extremity was immobilized in a cast, there was atrophy in spite of exercise performed by the uninvolved limb. Kruse & Mathews[12] using normal college students as subjects, found no increase in strength in the contralateral unexercised limbs. Recently Wellock[13] reported bilateral increase in muscle strength following unilateral exercise. Gregg[14] studied electromyographic effects of exercise, using skin electrodes. His studies were limited to the biceps and triceps muscles. He found that overflow to the unexercised contralateral muscles did not occur during simple non-resistive exercises, or during isometric contraction of the biceps brachii. With resistance, overflow appeared first in the opposite triceps, and with increasing resistance activity in the contralateral biceps also appeared.

Method

In the present experiment, the eight channel Grass ink writing encephalograph (fig. 1) was used. Surface electrodes in form of eight millimeter silver discs were mounted in pairs one inch apart, on specially constructed plastic plates (fig. 2). These plates were attached to an adjustable rubber strap in such a manner that one pair of electrodes was placed over the motor point of the agonist and one pair over the antagonist.

Electrodes were applied to the biceps, triceps, quadriceps femoris, and hamstrings bilaterally, and were placed parallel to the direction of the muscle fibers (fig. 3). The machine was standardized so that the exercised muscle registered excursions of one millimeter for every 100 microvolts, while the potentials of

Fig. 1—Eight channel Grass encephalograph machine and subject positioned for right biceps exercise.

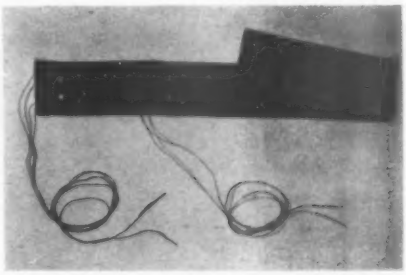

Fig. 2 — Specially constructed plastic plates with silver electrodes, mounted in pairs on adjustable rubber strap.

Fig. 3 — Showing encephalograph junction box with eight paired wires and application of double electrode to agonist and antagonist muscles on all four extremities.

non-exercised muscle were recorded at five millimeters per 100 microvolts. This differential in standardization was necessitated by the high potentials of the exercised muscle. The paper moved at a speed of 15 millimeters per second. The subjects were relaxed in the supine position and no straps or other artificial means of fixation were used for stabilization of the body.

The quadriceps exercise consisted of extending the knee from 90° flexion; all other extremities were supported in full extension. The biceps was exercised from full extension of the elbow to full flexion. Each subject was used only once to eliminate any possible effect of training. In the first series of six subjects, the right biceps was exercised against gravity alone and then with 10, 20 and 25 pounds of weight, followed by isometric contraction. Each cycle of exercises consisted of three repetitions. Similar experiments were conducted on the lower extremity in which the quadriceps femoris was the exercising muscle — first against gravity alone, then with loads of 10, 20 and 30 pounds, followed by an isometric contraction with the knee flexed 90°. The weight limits of 25 pounds for the biceps and 30 pounds for the quadriceps femoris were found to be the maximum which could be lifted without gross compensating movements in other parts of the body (tables 1 and 2). All subjects were normal, healthy, young, adult, males.

Results

The electromyographic potentials obtained from the various muscle groups while exercising the right quadriceps muscle are illustrated in figure 4. Motor unit activity is present in all muscles to a varying degree, with the greatest activity in the right quadriceps, this being the exercised muscle, and the least degree of activity in the right and left biceps. In order to obtain a true perspective of the total muscle activity in each of the muscles examined bar graphs were constructed to represent the electrical activity in each muscle, expressed in microvolts. Figure 5 represents the bar graph obtained after calculating the electrical potentials in microvolts.

From figure 5 it is apparent that by far the greatest activity was present in the exercised muscle. However, there was some degree of motor activity in all muscles tested. From this graph, it is apparent that in contrast to previous views, the contralateral muscle does not show the highest amplitude of all the non-exercised muscles and at no time did the electrical potentials in non-exercised muscles reach more than 20 per cent of the potentials in the exercised muscle. In figure 6 are represented the composite

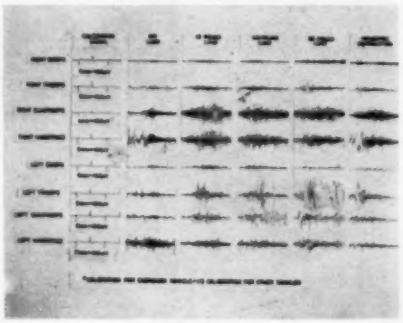

Fig. 4 — Electromyographic potentials obtained from muscles under examination with right quadriceps undergoing exercise. Calibration for exercised muscle is one-fifth of calibration of other muscles.

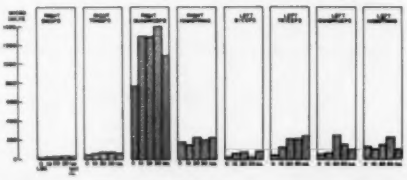

Fig. 5 — Bar graph representing electromyographic potentials of all muscles tested with right quadriceps exercised (in microvolts).

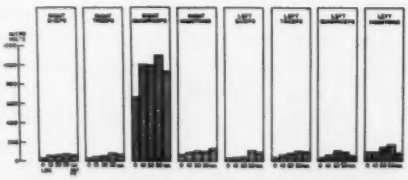

Fig. 6 — Bar graph representing average of six subjects whose right quadriceps was exercised (in microvolts).

Table 1: Right Biceps Muscle Exercised

Muscle	Right Biceps					Right Triceps					Right Quadriceps					Right Hamstring				
Load Lb.	0	10	20	25	Iso.	0	10	20	25	Iso.	0	10	20	25	Iso.	0	10	20	25	Iso.
Subject																				
C.A.	57.0	68.5	120.0	86.5	82.5	2.0	2.6	6.9	6.9	4.7	0.0	1.2	1.0	1.0	2.2	0.0	0.0	0.7	2.0	2.4
L.R.	87.0	33.7	95.2	103.0	102.0	6.3	11.5	11.7	10.9	7.2	14.9	12.3	18.0	23.2	13.6	5.5	3.7	5.0	4.8	4.0
K.B.	34.0	86.1	112.3	87.0	110.8	6.0	6.9	5.6	3.3	5.5	0.0	1.2	2.5	1.5	2.2	0.0	0.7	3.2	1.3	2.4
S.C.	81.2	76.0	99.0	108.4	65.1	19.0	28.0	10.6	12.5	7.6	5.0	2.6	7.2	8.2	7.0	6.4	4.0	9.4	9.5	6.2
B.W.	68.7	34.5	63.3	81.7	94.5	4.2	1.8	4.6	4.0	5.6	0.8	1.3	1.4	1.4	1.9	2.0	1.5	2.4	2.6	4.6
H.W.	91.4	82.2	93.4	94.0	73.6	4.0	5.5	8.0	10.8	9.0	0.0	0.0	0.0	0.0	0.0	0.9	0.9	0.9	1.5	1.0
Total	419.3	381.0	493.2	560.6	528.5	41.5	56.3	47.4	48.4	39.6	20.7	18.6	30.1	35.3	26.9	14.8	10.8	21.6	21.7	20.6
Average	69.9	63.5	82.2	93.4	88.0	6.9	9.4	7.9	8.1	6.6	3.4	3.1	5.0	5.9	4.5	2.5	1.8	3.6	3.6	3.4

Muscle	Left Biceps					Left Triceps					Left Quadriceps					Left Hamstring				
Load Lb.	0	10	20	25	Iso.	0	10	20	25	Iso.	0	10	20	25	Iso.	0	10	20	25	Iso.
Subject																				
C.A.	0.0	0.0	0.7	7.0	1.9	0.0	0.0	0.8	1.3	1.6	2.0	3.6	7.2	8.0	6.0	1.8	2.0	4.8	4.8	4.7
L.R.	1.6	1.3	1.8	2.3	1.3	12.0	8.6	9.6	13.9	6.3	4.3	2.6	2.5	2.6	2.1	4.5	3.8	4.5	4.4	4.5
K.B.	0.5	1.3	2.3	4.7	2.9	0.6	3.5	4.4	3.6	3.4	0.0	1.2	2.4	1.7	0.9	2.3	1.5	5.7	5.0	2.0
S.C.	1.5	1.7	2.9	4.0	1.8	3.8	0.9	3.2	7.8	2.4	4.4	1.2	4.2	4.4	1.2	2.9	2.7	5.8	4.6	4.2
B.W.	1.9	1.6	1.5	1.5	4.4	2.0	1.3	1.8	2.5	2.4	0.7	0.4	0.9	1.0	2.5	1.4	1.0	1.0	2.0	4.5
H.W.	0.8	0.9	1.0	1.4	1.4	1.2	1.1	1.3	1.5	1.2	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.7	0.8	1.4
Total	6.3	6.8	10.2	20.9	13.7	19.6	13.4	21.1	30.6	17.3	9.4	9.0	17.2	17.7	12.7	13.3	11.0	22.5	21.6	21.3
Average	1.0	1.1	1.7	3.5	2.3	3.3	2.2	3.5	5.1	2.9	1.6	1.5	2.8	2.9	2.1	2.2	1.8	3.7	3.6	3.5

Table 2: Right Quadriceps Muscle Exercised

Muscle	Right Biceps					Right Triceps					Right Quadriceps					Right Hamstring				
Load Lb.	0	10	20	30	Iso.	0	10	20	30	Iso.	0	10	20	30	Iso.	0	10	20	30	Iso.
Subject																				
B.R.	1.4	4.6	3.6	3.9	3.4	1.6	2.5	2.4	1.9	2.4	36.0	66.3	70.5	61.6	60.4	1.5	3.6	1.7	2.3	2.4
K.R.	1.0	2.5	2.3	2.5	2.0	2.6	3.8	3.8	3.6	3.2	42.5	43.6	41.8	34.5	32.0	2.2	5.0	7.9	3.6	16.7
B.E.	4.4	8.0	9.5	9.7	7.3	1.0	2.8	2.7	3.0	2.1	39.0	52.5	52.2	56.6	43.0	2.5	4.9	4.5	6.0	2.4
L.P.	1.0	1.4	1.7	2.0	1.7	2.3	3.3	4.0	4.0	3.4	38.4	64.8	64.4	70.4	58.0	9.0	7.6	11.5	10.0	11.6
M.C.	1.3	0.9	1.4	1.8	4.3	3.6	2.8	3.0	4.1	2.9	34.6	34.8	37.0	52.1	36.5	3.8	3.5	2.6	3.8	3.4
J.M.	0.9	0.6	0.8	2.2	1.4	0.0	0.0	0.0	8.0	8.0	16.8	41.8	46.5	54.8	49.2	3.0	1.7	2.5	4.3	3.3
Total	10.0	18.0	19.3	22.1	20.1	11.1	15.2	15.9	24.6	22.0	207.3	303.8	302.4	329.8	279.1	22.0	26.3	30.7	30.0	39.8
Average	1.7	3.0	3.2	3.7	3.3	1.8	2.5	2.7	4.1	3.7	34.5	50.6	50.4	54.9	46.5	3.3	4.4	5.1	5.0	6.6

Muscle	Left Biceps					Left Triceps					Left Quadriceps					Left Hamstring				
Load Lb.	0	10	20	30	Iso.	0	10	20	30	Iso.	0	10	20	30	Iso.	0	10	20	30	Iso.
Subject																				
B.R.	0.0	0.0	0.0	4.9	5.6	1.2	1.9	1.5	2.3	3.4	2.3	2.4	2.4	1.9	3.3	4.7	5.8	4.2	4.4	3.5
K.R.	1.5	2.6	2.5	5.5	2.5	1.2	2.7	2.4	4.9	3.3	1.4	2.2	7.7	9.2	3.0	8.2	3.5	6.9	13.0	3.9
B.E.	1.0	2.0	4.7	9.5	2.8	3.0	4.0	4.0	5.0	2.6	3.5	8.4	7.6	7.4	3.8	5.3	8.3	12.0	11.3	5.8
L.P.	1.8	3.2	4.0	1.8	4.4	2.8	6.3	10.3	10.2	12.2	2.7	3.3	12.2	7.8	4.9	6.4	5.0	7.6	11.1	5.0
M.C.	2.6	1.9	1.5	1.9	1.4	2.3	2.5	3.8	4.4	2.6	1.1	1.1	1.8	1.8	1.4	1.5	4.0	6.3	6.8	0.8
J.M.	3.0	1.8	1.4	10.2	11.0	1.6	2.0	1.2	4.4	5.3	0.8	1.3	0.7	0.8	0.9	2.0	1.8	2.5	4.7	5.6
Total	9.9	11.5	14.1	33.8	27.7	12.1	19.4	23.2	31.2	29.4	11.8	18.7	32.4	28.9	17.3	28.1	28.4	43.5	51.3	24.6
Average	1.6	1.9	2.3	5.6	4.6	2.0	3.2	3.9	5.2	4.9	1.9	3.1	5.4	4.8	2.9	4.7	4.7	7.2	8.5	4.1

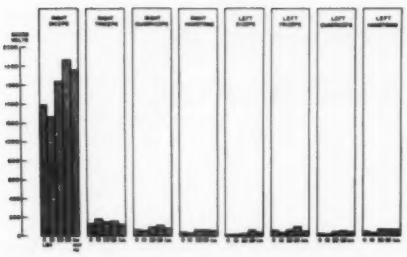

Fig. 7 — Bar graph representing average of six subjects whose right biceps was exercised (in microvolts).

values obtained by averaging the results of all six subjects whose right quadriceps muscle was exercised. Figure 7 represents the composite of motor unit potentials obtained in the six individuals whose right biceps was exercised.

Discussion

Before analyzing results obtained from our studies, certain fundamental concepts must be re-stated. Exercise by definition is a volitional and purposeful coordinated muscle contraction to increase and maintain muscle strength and full range of motion. Petow and Siebert[15] clearly established the fact that nothing but an increase of intensity of work above that previously demanded of a muscle is the stimulus for an increase of muscular strength. This same concept was expanded and brought to the attention of the medical profession during and after World War II by De Lorme[16] in his work on progressive resistive exercises. While it is true that an analysis of individual electromyographic potentials cannot be used to quantitate accurately muscle strength, and particularly an increase in muscle strength, however, the amplitude and frequency of potentials show some degree of correlation with muscular activity which can be duplicated and can be used for comparison with other muscle groups.

With these facts in mind, analysis of the data obtained from these studies indicates: (1) the electromyographic activity is not limited to the contralateral muscle but is widespread throughout the body, involving muscles on the same side as well as contralateral to the exercised muscle, in the upper as well as in the lower extremities; (2) the contralateral muscle does not show the greatest electromyographic activity; (3) the electromyographic potentials in the non-exercised muscles are greatest in those muscles which are used to stabilize the body while exercise is being performed; and (4) at no time are the electromyographic potentials in non-exercised muscles greater than 20 per cent of the amplitude of potentials in the exercised muscle.

Mueller's studies indicate that exercise with less than 35 per cent of maximum strength will not increase muscle strength. Based on this concept, our studies show that the maximum muscle contractions found in the non-exercised muscles never reach this minimum value necessary to increase muscle strength. Recognizing the lack of absolute correlation between electromyographic potentials and muscle strength, the authors plan to repeat these studies using tensiometer or strain gauge readings as criteria for muscle strength in the exercised and non-exercised muscles.

Summary

Electromyographic studies of muscles in the upper and lower extremities were performed to evaluate the effect of exercise of one muscle upon non-exercised muscles. The subjects were normal healthy young men. The greatest electromyographic activity was found in the exercised muscle. Electromyographic potentials of low amplitude and low frequency were found in all non-exercised muscles studied. These potentials were not limited to the contralateral muscle but were wide-spread throughout all four extremities. The electrical activity appeared to be greatest in those muscles required to stabilize the body while performing exercise. The amplitude and frequency of these potentials would indicate that they were of insufficient magnitude to constitute exercise effect.

Acknowledgment: The authors wish to thank Dr. Karl Harpuder, Senior Consultant in Physical Medicine and Rehabilitation for his valued suggestions and criticisms and to Mr. Morris Vogel, Chief of Physical Therapy for the technical assistance in performing the exercise studies.

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Information relative to securing reprints of this study may be had by checking the Reader Service column on page iv of this issue.

Our slip is showing . . .

The editorial staff sincerely regrets that the study **European Spas** as published in the November 1960 issue of the journal did not include the name of William Bierman, M.D., 750 Gonzalez Drive, San Francisco, as the senior author of this contribution and naming him as the individual to whom requests should be made for reprints or other pertinent information covering this article.

The study **Hospital-Centered Vocational Rehabilitation** authored by Robert H. Manheimer, M.D., et al, was not presented at a seminar sponsored by the American Rehabilitation Foundation as stated in the October 1960 issue of the journal.

A Comprehensive Evaluation of the County Hospital Patient

James W. Rae, Jr., M.D.
Edwin M. Smith, M.D.
and
Alma J. Murphy, Ph.D.
Ann Arbor, Mich.

● The Department of Physical Medicine and Rehabilitation and the Division of Gerontology at the University of Michigan, with the cooperation of other interested groups within the University, are conducting a study of patients in selected county medical care facilities in Michigan. The purpose of the project is twofold: to determine the medical status, functional ability, psychosocial level and vocational potential of patients in such institutions, and to introduce a demonstration program through staff and community organization to help the patients reach their maximum level of physical, social and vocational independence. The program is now underway in two county hospitals while patients in a third hospital without such a program are serving as a group for comparison. This article describes the method of the "multiple-discipline approach" used to evaluate the rehabilitation potential of the chronically ill patients in the Michigan county medical care facilities. A summary of the many medical entities found in the patients is presented as well as some of the remedial medical and physical restorative procedures recommended.

County farms and infirmaries long have served as repositories for the indigent ill and incapacitated, the homeless, the mentally deficient and others unable to care for themselves. Traditionally these institutions provided inmates with food, shelter, and simple custodial and nursing care, often for the remainder of their lives.

In recent years, however, the pressure of increasing numbers of chronically ill aged persons, together with the stimulus of state and federal aid, have brought about changes in the nature of county institutional programs. Infirmaries are being converted into medical care facilities, or hospitals, and custodial care is yielding to programs which emphasize medical and skilled nursing regimens. Although care has improved, only a few county hospitals offer modern chronic disease programs employing rehabilitation concepts.[1, 2] The development of these programs frequently is hindered by lack of funds, community apathy, pessimistic attitudes of staff and difficulty in securing specialized personnel.

The availability of these programs in the county hospital, moreover, is often of importance to the entire community. In many areas, this facility is the only hospital — public or private — which offers long-term medical care for the chronically ill. In Michigan, shortages of chronic disease beds create demands for admission of private patients to county hospitals in addition to persons counties are legally required to serve.[3]

University of Michigan Rehabilitation Project

In Michigan as in other states, new county facilities are being constructed and existing structures enlarged and improved. To aid in the planning and development of programs for these new facilities, an interdisciplinary research team from The University of Michigan has undertaken a project to study care needs of patients in selected county hospitals, and to introduce demonstration rehabilitation programs based on the study findings.

First Phase: Survey of Michigan County Hospitals

The first phase of the project was a general exploratory survey of the state's 39 county hospitals.[4] This survey was used to obtain an over-all picture of these institutions as well as to select several typical facilities for more intensive study. Some of the major findings are described below.

A. *Administration.* The typical county hospital in Michigan contains 80 beds which are located in a renovated infirmary building constructed before the turn of the century. The program is

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Professor and Chairman, Department of Physical Medicine and Rehabilitation, Medical School, University of Michigan, Ann Arbor.
Assistant Professor, Department of Physical Medicine and Rehabilitation, Medical School, University of Michigan, Ann Arbor.
Research Associate, Department of Physical Medicine and Rehabilitation, Medical School, University of Michigan, Ann Arbor.

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administered by the county welfare department, with financial contributions coming from both state and county government. The cost of caring for a patient in the average county facility in 1957-58 was slightly over $200 per month.[5]

B. *Staff Services.* Thirty of the 39 medical care facilities employ a full or part-time physician. The nine remaining institutions purchase medical services on a call basis. All but two institutions have one or more registered nurses and each has, on the average, 20 nurse aides and orderlies. Only a handful, however, employ a physical therapist, occupational therapist, social worker or nutritionist. None of the hospitals have vocational training or sheltered workshop programs.

Nursing care primarily is of the maintenance type, and simple medical treatment is carried out as required. Much of the staff's time is spent in providing personal care for those patients who cannot care for themselves, and relatively little attention is given to functional training for disabled patients. However, nursing personnel generally do encourage proper bed positioning, daily ambulation and physical activity.

C. *Patient Population.* The median age of the patients is 73 years and more than three-fourths are over 65 (tab. 1). The population contains slightly more men (55 per cent) than women. Only 13 per cent of all patients have a living spouse. Almost 60 per cent have been hospitalized for at least one year, 29 per cent for three or more years, and 17 per cent for five or more years. The county hospital is clearly a long-stay institution and is often looked upon as a terminal institution by the general public, the patients and by the staff itself.

Patients customarily are admitted to the county hospital when they have become incapacitated to the point where they can no longer care for themselves. Persons without a spouse or other relatives in the community tend to be admitted sooner than those with established social ties. Since private nursing homes often are unable to care for patients with the more difficult nursing problems, such "problem cases" gravitate toward the county institution. County hospitals thus contain a mixture of patients who require widely diversified types of care.

Table 1: Selected Demographic Characteristics of Patients in County Medical Care Facilities in Michigan*

	Per Cent
Age	
Under 65	22
65 to 74	26
75 to 84	34
85 or over	18
	100
Average age: 73 years	
Sex	
Women	45
Men	55
	100
Marital Status	
Married	13
Widowed, divorced, separated	55
Single	26
Not ascertained	6
	100
Length of stay, in excess of:	
1 year	59
3 years	29
5 years	17
10 years	7
Average length of stay: 3 years	

*Based on a 1957 survey of all nursing facilities in Michigan by the Bureau of Public Health Economics, School of Public Health, The University of Michigan. Data to be published in a forthcoming monograph by the Bureau.

Second Phase: Patient Evaluation

The next phase of the project consisted of intensive medical, functional and psychosocial evaluations designed to provide a comprehensive picture of the patients and to serve as the basis for determining their specific care needs. Two typical hospitals, containing a total of 125 patients, participated in the evaluations and in the subsequent development of indicated restorative programs. A third, similar hospital, which received no special programs, served as a control.

Included in the evaluation of each patient was a medical history and physical examination by an internist, an examination by a neurologist and an evaluation of physical disability and performance of activities of daily living by a rehabilitation team. Laboratory tests used included a chest microfluorogram, an electrocardiogram, two-hour postprandial blood sugar determination, hematocrit, Kahn serologic reaction, urin-

alysis, audiogram and a full mouth x-ray. Psychosocial evaluations provided data on patients' morale, self-image and social relationships.

A. *Preliminary Findings.* Although data from the patient evaluations still are being processed, some preliminary observations can be reported. As would be expected, virtually all of the patients have been hospitalized because of a chronic disease.[6] While the nature and severity of the conditions varies considerably, 74 of the 125 patients (59 per cent) have chronic disabilities which cause them to depend upon an attendant in carrying out one or more of the basic activities of daily living. The remainder of the group, although not physically dependent, require some degree of daily supervision and, in a few cases, specialized nursing services.

The causes of physical dependency often are multiple but nine out of 10 patients with functional impairment have disorders involving the nervous system (tab. 2). Cerebral arteriosclerosis, of course, predominates as the underlying pathologic process,[7] and is manifested as a cerebral vascular accident in one-third, and as a chronic brain syndrome in more than half, of the dependent group. Other causes of invalidism include musculoskeletal disorders (30 per cent), severe visual loss (12 per cent) and endocrine or metabolic disorders (8 per cent). Less than five per cent are incapacitated by cardiac disease, although heart disease produces mild to moderate limitation of activity in nearly one-fourth of the hospital population. Chronic disorders frequently were detected in other body systems but such diseases seldom make patients dependent upon an attendant for their personal care.

Incontinence also impairs the ability of some patients to function in normal living situations. Forty-two per cent lack bladder control and 34 per cent lack bowel control at least part of the time. However, most of the incontinent patients also have other difficulties which create physical dependency.

Similarly, communication handicaps often interfere with function. A survey in one of the hospitals indicated that 13

Table 2: Disorders Responsible for Physical Dependency of 74 Patients in Two County Medical Care Facilities

Disorder	Number of Patients*	Per Cent
Nervous System	68	92
Chronic Brain syndrome	42	
Hemiplegia	25	
Parkinson's disease	3	
Primary Cord disease	4	
Other	6	
Musculoskeletal System	22	30
Deformity secondary to trauma	7	
Arthritis	8	
Other	8	
Vision	9	12
Cardiovascular System	3	4
Endocrine and Metabolic Systems	6	8
Other	1	1

*Some patients have multiple disorders.

per cent of the patients have severe communication handicaps while 34 per cent are moderately handicapped; another 34 per cent have a mild deficit. The handicaps include speech impairment in 45 per cent of the patients (compared with an incidence of two per cent in the general population) and measurable hearing defects in 51 per cent (in contrast to seven per cent among adults in general).[8]

Some of the consequences of prolonged institutionalization, chronic disease, idleness and impaired communication were revealed by the psychosocial evaluations carried out in the two hospitals. The typical behavior pattern among patients is one of withdrawal, hostility and emotional instability. Responsiveness to stimuli is limited and group cohesion is almost non-existent.[9]

Possible metabolic sequelae of chronic invalidism and inactivity were investigated by measurement of carbohydrate utilization. On the basis of criteria established for healthy, active middle-aged persons, over a third of the patients have decreased glucose tolerance sufficient to indicate diabetes mellitus. The prevalence of abnormal carbohydrate metabolism was shown to have a direct relationship with age and an inverse relationship with the level of physical activity. However, since the amount of activity generally decreases with age, it is difficult to ascertain the relative influence of

each of these factors on carbohydrate tolerance.[10]

A high rate of dental disease also is characteristic of the county hospital population. More than two-thirds of the patients at one of the study hospitals were found to be completely edentulous, and only one-quarter of these have satisfactory dentures. Three-quarters of the remaining patients have carious teeth and practically all exhibit some degree of periodontal disease.[11]

B. *Care Needs Identified.* After completing the evaluations, the medical team determined the care needs of each patient, based on the survey findings. It was found that patients' needs could be met for the most part, by three basic programs: (1) active treatment, (2) supervisory care and (3) maintenance nursing (tab. 3).[12]

Approximately one-third of the patients was expected to benefit from an active treatment program emphasizing medical, functional and physical restorative services. As table 4 indicates, 64 per cent of those assigned to this program primarily are in need of physical rehabilitation, while 16 per cent require long-term medical treatment. The remaining 20 per cent need a combination of both types of therapy. Although many of these patients would continue to need some degree of nursing care after rehabilitation, others might be discharged to a non-nursing setting.

Another third of the patients needs only supervisory care. Their medical problems are not sufficiently serious to require hospitalization or nursing care. They do, however, need room, board and at least some supervision and assistance in managing their affairs. Most of all, these patients need a normal, home-like environment, away from sickness and hopeless invalidism. The majority are institutionalized because of mild senility or an accumulation of the "infirmities of age." They are housed in the county hospital primarily because there is no other, more suitable arrangement for them in the community.

The remaining 30 per cent of the population needs permanent maintenance nursing care; these patients probably will require such care for the balance of their lives. Due in large part to advanced senility, patients in this category could not be expected to improve significantly with active treatment. However they should still benefit from a nursing program based upon "maintenance rehabilitation," that is, a program designed to preserve existing levels of functioning as long as possible.[2]

Patients in all three categories can be expected to benefit from stimulating activities. Participation in such activities should result in better personal adjustment and stronger and more satisfying social relationships within the patient population.[9]

Table 3: Type of Care Needed by 125 Patients in Two County Medical Care Facilities

Program	Number of Patients	Per Cent
Active Treatment	45	36
Maintenance nursing	38	30
Supervisory care	38	30
Treatment in other types of hospitals	4	4
Total	125	100

Table 4: Treatment Needs of Patients Assigned to Active Treatment Program

Treatment Needs	Number of Patients	Per Cent of Active Treatment Group	Per Cent of All Patients
Physical restorative services	29	64	23
Medical treatment	7	16	6
Physical restorative services and medical treatment	9	20	7
Total	45	100	36

Third Phase: Programming

Demonstration programs designed to meet patient needs have been introduced into the study hospitals. For the active treatment group, physical and functional restorative services are offered to complement existing medical care. A broad activity program — including a sheltered workshop, crafts, recreation and "friendly visiting" — is available to all patients. Discharge arrangements are made for those able to live in non-nursing settings. Advisory committees and

volunteer workers have provided valuable community support for the project.

At the conclusion of the demonstration period, patients will again be evaluated to determine the extent of improvement in functional and psychosocial status, as compared with improvement of those in the control hospital who received no restorative services.[13] The project team also will study the impact of the new programs upon the hospital and the community.

Summary

The county hospitals surveyed in this project house many physically disabled and socially crippled people. Yet careful evaluation reveals the fact that a sizeable number are potentially restorable to higher levels of health and physical functioning — some to the point of discharge into the community. Another bloc of patients needs supervisory, rather than nursing, care. Such persons could live outside of a hospital or nursing facility if suitable accommodations were available. To meet the variety of needs of county hospital patients requires careful evaluation of incoming patients; adequate medical and functional restorative services; a broad program of activities for patients and an effective, community-supported discharge program.

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Information relative to securing reprints of this study may be had by checking the Reader Service column on page iv of this issue.

. . . there is nothing so fatal to character
as half-finished tasks.

— DAVID LLOYD GEORGE

Rehabilitation of the Rheumatoid Hand by Surgical Means

Edward D. Henderson, M.D.
and
Paul R. Lipscomb, M.D.
Rochester, Minn.

● In the past 10 years surgeons interested in the hand have demonstrated that some disabling conditions and deformities of the hand due to rheumatoid arthritis may be treated effectively by surgical means. In certain of these conditions surgical treatment appears to offer real advantages over the traditional, more conservative, methods. This paper points out some of the indications for operation and the results to be expected. The authors emphasize that the operative approach is not used to improve the appearance of the hand but to improve function and to eliminate or reduce pain. Most of these operations can be done with use of local anesthesia. The convalescence from primary surgical procedures, particularly the arthroplasties of the metacarpophalangeal joints, may require several months, with gradual improvement in function over the entire period of convalescence. Once a good result has been obtained, the improvement seems to be maintained, providing there is no serious flareup of the arthritis after the operation. Some of these operations have been done as long as four and five years ago. At present the place of surgical methods in the general scheme of treatment of rheumatoid arthritis is not formally established. It seems important, therefore, for physicians to be aware of the possibility of improving by surgical means the function of hands crippled by rheumatoid arthritis.

In the past 10 years surgeons interested in the hand have demonstrated that some disabling conditions and deformities of the hand due to rheumatoid arthritis may be treated effectively by surgical means. In certain of these conditions surgical treatment appears to offer real advantages over the traditional, more conservative, methods. We anticipate that within the next five years the proper role of surgical methods in treating the hand affected by rheumatoid arthritis will have been established.

Up to the present, surgical treatment has been reserved for those cases in which medical measures and physical therapy (including splinting, heat, massage, active exercises, and gentle stretching of stiffened joints) have been ineffective in preventing deformity and loss of function of the hand and of the upper extremity in general.

Operative measures clearly are indicated for the patient who can no longer button a coat, write a letter, feed himself, or do other fine work with his hands. Furthermore, painful conditions caused by tenosynovitis or progressive destruction of the joints may be relieved by surgical treatment.

Our task is to determine in what instances surgical measures will be more effective than conservative measures in restoring function and to evaluate the results of surgery. For this purpose it would be well to study the rheumatoid process as it involves each of the structures of the hand[1, 2] to see when surgical measures best apply.[3, 4] The primary purpose of surgery of the hand is to restore function, and the secondary consideration is the elimination of pain. Surgical procedures for improving the appearance of the hand are seldom successful and are not recommended.

Tenosynovitis

One of the early manifestations of rheumatoid arthritis of the hand may be tenosynovitis, which may involve any of the tendon sheaths at the wrist or in the hand. In the stage of the disease when the patient complains of stiffness and swelling of the hand in the morning and difficulty in making a fist until he has been up for an hour or so, the diagnosis may be difficult; crepitus on motion of the tendons is probably minimal, and the tendon sheaths will be only mildly tender. However, in certain instances the symptoms will strongly suggest tenosynovitis.

Carpal Tunnel Syndrome. The most dramatic example is the so-called carpal tunnel syndrome, in which the symptoms are due to tenosynovitis of the sheaths of the flexor tendons at the wrist inside the carpal tunnel.[5] As the tendon sheaths swell they press the median nerve against the transverse carpal ligament and the patient experiences pain in the palm of the hand, in the fingers, and, later, in the wrist, forearm or even in the

From Section of Orthopedic Surgery, Mayo Clinic and Mayo Foundation; the latter is a part of the Graduate School of the University of Minnesota.

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shoulder. Paresthesia, numbness and, subsequently, thenar atrophy occur. The pain characteristically comes on at night. The patient may wake up and have to shake his hands to rid himself of the pain and paresthesia. These symptoms may appear also in the daytime when the patient is doing some fine work with the hands, such as reading while holding a heavy book, writing, or sewing. Careful questioning usually reveals that the chief sites of pain and paresthesia are in the regions of the sensory distribution of the median nerve. The diagnosis may often be made by means of an injection of hydrocortisone into the carpal tunnel; within 24 hours of the use of the corticosteroid the symptoms will be much relieved if compression of the median nerve is due to rheumatoid tenosynovitis. The injection may then be repeated two or three times at intervals of three to six weeks. If the symptoms are not controlled by this means, surgical treatment is indicated and nearly always eliminates the symptoms.

The operation usually is done through an incision along the thenar crease while using local anesthesia and a pneumatic tourniquet. A longitudinal incision through the transverse carpal ligament releases the pressure on the median nerve. The surgeon must then decide whether to perform synovectomy of the flexor tendon sheaths. Usually within hours after the operation the patient notices definite improvement in sensation in the fingers and a lessening of the pain. This rather dramatic result has been a great source of satisfaction to us since many of these patients were thought to have compression of a cervical nerve root or various forms of neuritis or neuralgia in the upper extremity.

Tenosynovitis With Rupture of the Tendon.[6] Tenosynovitis of tendon sheaths may require synovectomy and probably demands synovectomy in cases of chronic thickening of the synovial tendon sheath if this condition is not improved after a series of injections of a corticosteroid into the sheaths. If the tenosynovitis is present for long periods, serious disability to the hand may develop. For example, long-standing tenosynovitis may result in spontaneous rupture of any of the tendons. Certain tendons in certain sites are most commonly affected. Thus, the tendon of the flexor pollicis longus may rupture and pull loose at its insertion. This may be true also of the tendons of the flexor digitorum profundus. On the dorsal side, the tendon most commonly ruptured is that of the extensor pollicis longus; it tends to rupture in the region where it passes Lister's tubercle. The common extensors of the fingers may rupture at the level of a dorsally dislocated distal end of the ulna. The mechanism leading to rupture of the tendons is not completely understood. It may be that the tenosynovitis causes degeneration and fraying of the tendons, with eventual rupture, or that the rheumatoid involvement of adjacent joints and bony structures causes attrition of the tendon as it passes over these bony prominences; perhaps both of these factors play a role.[7-9]

Early diagnosis of a ruptured tendon is essential. The patient will usually recognize that something has gone wrong; he may have heard a snap or noticed the loss of function. However, the physician may experience difficulty in confirming that rupture has occurred and in locating the position of the break. For instance, if the common extensor tendons of the three fingers on the ulnar side have ruptured, it is easy to confuse this with a flexion deformity at the metacarpophalangeal joints and ulnar deviation due to pathologic changes in the joints themselves. A careful observer will note that when the patient tries to extend the involved finger the appropriate common extensor tendon does not stand out on the dorsum of the hand and that there is no real ulnar deviation of the finger; furthermore, dorsal subluxation of the ulna at the wrist usually is noted in rupture of extensor tendons. In dealing with the hand affected by rheumatoid arthritis, one must be thinking of and looking for rupture of tendons in order to make the diagnosis.

Although splinting may protect tendons for a long time in rheumatoid arthritis, it would seem logical to perform synovectomy fairly early in the course of the disease when the tendons are in jeopardy from a combination of tenosynovitis and

involvement of the adjacent bones or joints. Furthermore, in the case of the extensor tendons at the wrist, the distal end of the ulna probably should be resected and any osteophytes or sharp points removed from the bones of the wrist joint in order to prevent rupture of tendons. Once rupture has occurred, surgical treatment is the only possible management. This consists of first locating the ends of the tendon, partially excising the tendon sheath and then doing either a tendon graft or tendon transfer. If one is careful to cut away all diseased portions of tendon and to make the anastomoses or grafts between normal-appearing sections of tendon, the results are almost always satisfactory.

Tendon transfers or grafts should be done no later than a few weeks after a spontaneous rupture. If surgical intervention is delayed beyond this time, contracture and fibrosis may develop within the muscle of the tendons that have ruptured; repair then is not as satisfactory as it would be in the case of a fresh rupture.

Trigger Finger. Tenosynovitis of the flexor tendons in the palm of the hand may cause so-called trigger finger, in which the finger becomes painfully locked in a position of extreme flexion or extension. This phenomenon may be due to swelling of the tendon sheath affected by rheumatoid tenosynovitis; the thickened portion, or proximal pulley, becomes so swollen that the tendon has difficulty in passing through it. Rheumatoid nodules or loose bodies may develop within the tendon sheath and cause locking of the tendon as it passes through the proximal flexor pulley. The tendon itself, as a result of the rheumatoid process, may develop a local swelling and become fixed under the pulley. If this condition is not improved after local administration of a corticosteroid, an operation, using local anesthesia, is indicated. A transverse incision is made and the locked tendon is freed by sectioning the proximal flexor pulley longitudinally, with or without resection of a portion of the flexor tendon sheath.

Involvement of the Joint. Of course tenosynovitis and rheumatoid nodules are not the only manifestations of rheumatoid arthritis of the hand. Any of the numerous joints of the hand and wrist may become involved at any stage of the disease.

The Importance of the Wrist. The wrist joint is frequently affected and may become disabled if there is enough muscle spasm to pull the wrist into flexion, a poor functional position. The fingers and thumb lose much of their ability to execute pinching movements and lose almost all their power of flexion when the wrist is fully flexed. The wrist joint is extremely important to the function of the hand and no surgery of the hand itself should be undertaken unless the patient can extend the wrist to a position of 30 to 45 degrees of dorsiflexion. In this position, the pinching, grasping, and hooking powers of the hand are maximal.

If the disorder of the wrist is not improved after splinting, injections of a corticosteroid, and other conservative measures, arthrodesis of the wrist or dorsal-wedge osteotomy is sometimes necessary to restore the position of function. As mentioned earlier, resection of the distal end of the ulna may be beneficial for the function of the wrist if there are subluxation and pain at the joint.

Involvement of the Thumb

In the hand itself, the metacarpophalangeal joints and the proximal interphalangeal joints are the ones most commonly involved in rheumatoid arthritis. The distal joints are rarely severely deformed except in the thumb. The thumb is an entity in itself, of course, and an extremely important one. The tip of the thumb must be opposable to the tips of the fingers for good pinching and grasping function. In advanced stages of arthritis, the metacarpophalangeal or interphalangeal joints of the thumb may become so painful and unstable as to make the thumb practically useless. In these cases, an arthrodesis of the involved joint, with the thumb in good position for opposition, restores good function to the thumb. If the first carpometacarpal joint is also painful and stiff, it is possible to restore some motion to the thumb even after arthrodesis of

the other two joints by resecting the greater multangular bone, thus lessening pain in the entire thumb.

Contracture of Intrinsic Muscles. In the metacarpophalangeal joints, the arthritic process gives rise to a fairly regular progression of signs and disabilities. In the early stages, either because of protective muscular spasm or of involvement of the intrinsic muscles themselves, intrinsic muscular overpull or contracture may occur. As a result, the metacarpophalangeal joints tend to become flexed and the proximal interphalangeal joints become hyperextended. This situation may occur before there is any clinical or roentgenologic evidence of involvement of the metacarpophalangeal joints. In that case, resection of a triangular portion of the extensor aponeurosis in the proximal portion of the phalanx, the so-called Littler operation, will diminish the overpull of the intrinsic muscles and allow restoration of normal function of the hand. This condition rarely occurs alone, however. Intrinsic contracture usually is accompanied by evidence of rheumatoid arthritis involving the metacarpophalangeal joints of the fingers. The joints become swollen and warm, and they lose mobility. This condition may be accompanied by the intrinsic contractures and, as the disease progresses, by ulnar deviation of the fingers. Eventually destruction of the metacarpophalangeal joint with dislocation and severe ulnar deviation may take place. When the metacarpophalangeal joint is swollen or the capsule is distended and the extensor hood stretched, injections of a corticosteroid locally should be used to try to reduce the swelling, tension, and distention. If this does not result in good clinical improvement, synovectomy of these joints should be considered. Synovectomy will protect the joint surfaces and prevent the progression of deformity in these joints about as well as this operation does when used in the knee joint.

Ulnar Deviation of the Fingers. If the deformities have progressed to the extent that the radial fibers of the extensor hoods have stretched and allowed a displacement of the common extensor tendons into the groove on the ulnar side of the joint, ulnar deviation of the fingers results. Synovectomy can be performed and the fibers on the radial side imbricated to shorten them, restoring the common extensor tendon to the mid-axis of the joint. In an early stage of the disease, this procedure usually restores the position of the fingers and greatly increases the patient's ability to pinch. In the opinion of some surgeons, the tendon of the extensor indicis should be used at the same time to reinforce the first dorsal interosseus muscle, thus permitting better pinching movements between the index finger and thumb.[10, 11] As the condition worsens and the ulnar deviation of the fingers becomes more pronounced, the base of the proximal phalanx tends to subluxate to the volar and ulnar side of the head of the metacarpal and may dislocate completely. If this has occurred, the ulnar fibers of the dorsal aponeurosis of the extensor hood and the flexor tendons have shortened, and it is better to resect a portion of the head of the metacarpal rather than to try to lengthen these structures.

In replacing the base of the proximal phalanx to the end of the metacarpal bone, it is better not to mold the base of the phalanx but to confine all surgical measures to the heads of the metacarpals. Also it is probably not well to try to use any interposing membranes such as fascia when performing this resection, or arthroplasty, as it may be called. It is astonishing how well a combination of arthroplasties of the metacarpophalangeal joints and arthrodeses of badly deformed interphalangeal joints can improve the function of the hand. In this case, we are talking about almost hopelessly crippled and grotesquely deformed hands. The improvement in function is dramatic to the patient and to the surgeon, but it is very difficult to describe.

Summary

Many surgical procedures can be performed on the tendons and joints of the hand affected by rheumatoid arthritis. We have tried to point out some of the indications for operation and the results to be expected from these

procedures. In our experience the results have been good, in some cases dramatically so.

We wish to emphasize that the operative approach is not used to improve the appearance of the hand but to improve function and to eliminate or reduce pain. Most of these operations can be done with use of local anesthesia. The convalescence from primary surgical procedures, particularly the arthroplasties of the metacarpophalangeal joints, may require several months, with gradual improvement in function over the entire period of convalescence. Once a good result has been obtained, the improvement seems to be maintained, providing there is no serious flare-up of the arthritis after the operation. Some of these operations have been done as long as four and five years ago.

At present the place of surgical methods in the general scheme of treatment of rheumatoid arthritis is not formally established. It seems important, therefore, for physicians to be aware of the possibility of improving by surgical means the function of hands crippled by rheumatoid arthritis.

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Information relative to securing reprints of this study may be had by checking the Reader Service column on page iv of this issue.

The Nature of the Motor Deficit in Double Athetosis

Thomas E. Twitchell, M.D.
Brighton, Mass.

● Athetosis is an instability of posture resulting from a disequilibrium between antagonistic physiologic mechanisms that are essentially reflex in nature. In the hands and feet these are the grasp reflex, determining flexion and adduction of fingers and toes, and the avoiding response determining extension and abduction. An imbalance of analogous reactions of the lips and tongue causes periodic pursing and parting of lips and protraction and retraction of tongue, while the purposeless movements of the head are related to visually determined pursuit and adversive reactions and poorly integrated righting reflexes. Inability to suppress the antagonistic member of one of these opposing responses impairs purposive movement in patients with double athetosis. In general, avoiding responses are prepotent leading to difficulty in fixing the eyes on an object, difficulty in reaching and grasping, and defective progression of gait. Less frequently, over-activity of grasping responses causes difficulty in releasing an object grasped. Further motor deficit results from inability to integrate neck and labyrinthine reflexes causing not only defective limb extension and adduction but also associated and mass movements. An intermittent intense resistance to passive movement in the limbs is related to overactive contact reactions and is identical in nature to the phenomenon of dystonia. All of these phenomena of double athetosis can be demonstrated in normal infants at certain stages of development and are of identical physiologic nature. The motor deficit of double athetosis, therefore, appears to result from defective sensory-motor integration with corresponding hypertrophy of infantile responses.

Athetosis is an instability of posture characterized by periodic alternations of posture in various parts of the body. In the upper extremity this occurs as a periodic flexion and adduction of the fingers alternating with extension and abduction, these movements often being accompanied by alternating pronation or supination of the hands. There may be various lateral and dorsi-ventral deviations of head and eyes, alternating pursing and parting or retracting of the lips, commonly associated with some protrusion and retraction of the tongue. Involuntary movements of the lower extremities are less frequent, but may occur as flexion-adduction of the toes alternating with some extension-abduction, these movements also being frequently accompanied by intermittent inversion and eversion of the foot. The "involuntary movements" characteristic of athetosis are absent when the patient is at complete rest, but occur when he attempts any spontaneous movement or is under emotional stress.

This paper is concerned with the results of investigations carried out on 30 children afflicted with double athetosis and ranging in age from three to 16 years. This was a clinical-physiologic study to analyze and define the various mechanisms, essentially reflex in nature, which account for the motor deficit in double athetosis. In addition pertinent findings from a similar type of study of 200 normal infants, ranging in age from one day to 12 months of age, are reported. This investigation is currently underway to determine more precisely the neurophysiologic mechanisms of normal motor development.

The extremes of posture which in alternation constitute athetosis may be elicited reflexly through their natural biologic stimuli. The extension and abduction of the fingers may be elicited by a light distally moving contactual stimulus over the dorsum of the hand, the outer border of the hand, or palmar surface of the fingertips. The opposite posture of flexion and adduction may be elicited by a more deeply pressing distally moving contactual stimulus to the medial aspect of the palm, the stimulus being drawn out between the thumb and index finger, or by a distally moving stimulus out from the palm onto the proximal segments of the fingers. This reflex extension-abduction of the fingers oftentimes is accompanied by some pronation of the hand and the flexion-adduction by some supination. These antagonistic responses may be fractionated so that by limiting the stimulus to the dorsal or palmar aspect of one finger, that finger may be made to flex or extend alone. In some patients the receptive fields for the two antagonistic reactions overlap so

From the Division of Neurology, Joseph P. Kennedy, Jr. Memorial Hospital, Brighton, Mass., and the Tufts University School of Medicine, Boston, Mass.

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that contact in the region of the third metacarpophalangeal joint could initiate several cycles of alternating flexion and extension of the fingers (athetosis).

Analogous reactions may be elicited reflexly in the feet. Extension and abduction of the toes follows from a distally moving contact stimulus of the dorsum of the foot or outer border of the foot, while a flexion-adduction response of the toes is obtained from a heavier contact stimulus moving distally over the medial sole. The extension-abduction is oftentimes accompanied by some eversion of the foot and flexion adduction by some inversion.

The antagonistic postures of lips and tongue also can be shown to have a reflex basis. Thus contact stimulation of the upper lip evokes pursing of the lips frequently accompanied by protrusion of the tongue. Contact stimulation of the lower lip causes parting of the lips or retraction of the corners of the mouth, commonly accompanied by retraction of the tongue.

Both in terms of motor response and receptive field the extension-abduction of fingers and toes is identical to a posture occurring in the limbs opposite to a parietal lobe lesion in a patient and called the "avoiding response" by Denny-Brown who has shown that both visual and contact stimuli may elicit it. The flexion-adduction response is the "grasp reflex" frequently associated with frontal lobe lesion. Commonly associated with reflex grasping are pursing of lips and protrusion of tongue obtained by tactile stimulus and pursuit movements of head and eyes from visual or tactile stimulus. Following parietal lobe lesion on the other hand one may obtain not only avoiding responses in the extremities, but also parting or retracting of the lips to tactile stimuli and adversive movements of head and eyes to visual or tactile stimuli.

Denny-Brown has pointed out that these reactions are normally in equilibrium both at cortical and subcortical levels of the nervous system and that a lesion abolishing one group of responses will release the other to over-activity. Athetosis represents a conflict or disequilibrium between these positive and negative responses, the grasp reflex and avoiding responses in the extremities and their analogous reactions in lips and tongue. The ability to fractionate the avoiding responses in the extremities and provides a physiologic basis for the common phenomenon whereby in athetosis one finger flexes while its neighbor extends and so on. The periodic "involuntary" lateral deviations of head and eyes result from a disequilibrium between the pursuit reactions (groping) and adversive reactions (avoiding).

Various abnormalities of resting posture in the limbs have been shown to result from faulty integration of neck, labyrinthine and body contact righting reflexes. Conflict between these reflexes leads to violent tremor at proximal limb segments during attempted voluntary movement or during emotional stress. Defects in head and trunk control result from conflicting labyrinthine and contact righting reflexes.

It is not the presence of so-called "involuntary movement" per se which impairs "voluntary" movement in these patients. It is rather an inability to integrate reflexes along with a corresponding hypertrophy of certain reactions which determines the physiologic basis for both the "involuntary movements" and the deficit in "voluntary" movements.

Although both positive and negative reactions can be obtained in these patients, disequilibrium of which is the basis for athetosis, the negative or avoiding reactions are prepotent and consequently all behavior is biased toward withdrawal.

There is a marked difficulty in extending the upper limbs toward an object. There may be initially a flexion of the arm away from the object. A coarse tremor of the upper extremity may then ensue, following which the arm may extend ataxicly toward the object, the hand may touch the object and immediately withdraw. If the object can be grasped it may be dropped immediately. Some patients may grasp the object but the power of grip is weakened. We have been able to show that the initial flexion of the arm following the intended extension results from an over-active visual avoiding response. Once contact with

the object is made, the tactile avoiding response may cause the hand to withdraw, particularly if contact has been made with the fingertips. It has also been possible to show that strength of finger flexion is inversely proportional to the facility of the avoiding response in the hand.

Infrequently the hand may approach an object with the fingers closed tightly in a tonic-grasp reflex with consequent difficulty in getting the hand to open unless the hand happens to touch the object in the field for the avoiding response, whereupon the fingers may open and indeed the limb may withdraw from the object.

Further difficulty in voluntary movement is related to inability to integrate neck, labyrinthine and righting reflexes. With the patient in the supine position there is frequently a great difficulty in making appropriate flexion and extension adjustments in the proximal limb segments as the limb is extended toward an object. Although part of this difficulty is related to the avoiding response, conflicting body contact righting reflexes also play a large role so that the movements can be executed with more dexterity if contact with the body is lessened (by allowing the patient to sit or holding him in the air). A few patients curiously show some difficulty in limb flexion while in the supine, extension being performed more readily. This difficulty has been shown to result from over-active static-labyrinthine reactions which may be overcome by placing the patient in the prone position.

Tonic-neck reflexes may be facile so that lateral deviation of the head produces not only the well known "fencer's position" of the extremities, but also dorsal and ventral deviations of head produce bilateral flexion and extension of upper and lower extremities as described by Magnus and his associates.

These reflexes may cause further difficulty with extension of the limb toward an object. Since the patient has difficulty in extending the limb, he will frequently bend the head and upper trunk forward to get closer to the object. Such a movement may induce increased flexion of the upper limb through action of the tonic-neck reflexes.

A few patients exhibit a markedly facile kinetic-labyrinthine response which produces phasic extension and abduction of the upper extremities with spreading of the digits, identical in form to the Moro response of the infant. These patients may be able to extend the limbs at the side, but are unable to adduct them around to the midline in order to get hold of an object.

The gait disorder in these patients is generally related to several mechanisms. The inability to stand appears to be primarily related to the over-active avoiding response of the lower extremities which opposes the positive-supporting reaction. Defective progression of the lower extremities and over-flexion at the hips and knees has clearly been related to exaggeration of the tactile avoiding responses of the feet. Some patients with over-flexion at proximal joints while walking have extension of the ankles which has been shown to result from fragmentary positive-supporting responses. Over-adduction of the legs or "scissoring gait" has been observed only in those patients in whom contact placing responses could not be obtained and can occur without spasticity in the adductor muscles.

We have been able to show that the peripheral speech mechanism is affected in similar ways to the extremities, and that dysarthria may result from a conflict between antagonistic responses. Thus pursing of the lips, protrusion of the tongue and approximation of tongue to hard palate, and velopharyngeal closure constitute positive reactions analogous to the grasping and groping responses in the extremities. The parting of lips, retraction of the tongue and velopharyngeal opening are analogous to the avoiding responses in the extremities. These negative responses are prepotent and consequently speech requiring lip approximation, certain fine tongue movements and velopharyngeal closure is most impaired.

Associated movements generally are closely related to the tonic-neck reflexes, while so-called mass movements occur as

part of the kinetic-labyrinthine responses. Resistance to passive movement may be increased and is not always in the form of true spasticity. In the proximal segments, particularly the enhanced neck, labyrinthine and righting reflexes contribute significantly to this. In the distal segments the avoiding response and grasp reflex mechanisms may be responsible for any increased resistance to passive movements, so that if one manipulates the extremity by contact with the hand or foot the resistance to passive movement may be intense. Such resistance, however, will disappear completely if the extremity is manipulated by grasping the forearm or leg. In some patients contact with the dorsum of the hand induces extreme flexion of the upper extremity with variable degrees of dystonia. This resistance, related to exaggeration of the contact reactions of the extremities, is the explanation for so-called "tension athetosis" and reveals the relationship of athetosis to dystonia.

The close similarity of the motor reactions in the patient with double athetosis and the normal human infant has been commented on by others. Such features as the resting posture in the supine position, the mass movements, the associated movements, various reflex phenomena and indeed the pattern of spontaneous movement in the infant and patient with double athetosis are striking. Indeed many have noted the athetotic postures in the infant hand and foot. We have been able to show that the responses of the normal infant are indeed identical in physiologic nature to those occurring in the patient with double athetosis. At birth flexion responses predominate and any spontaneous extension is generally in terms of modification of the kinetic-labyrinthine response, the Moro reflex. At birth avoiding responses are dominant in both hands and feet, and the automatic tactile grasping responses appear later in development. (The grasping response in early infancy is not the true grasp reflex but rather the proprioceptively determined traction response.) Following the appearance of the true grasp reflex in the infant hand and foot, disequilibrium between this response and the avoiding response results in true athetosis. The early walking movements of the infant with over-flexion of hips and knees and over-adduction of legs document the disequilibrium of supporting reflexes and avoiding responses of the lower extremities. Spontaneous adduction of the hands to the midline appears concomitantly with diminishing intensity of labyrinthine determined abduction. Although labyrinthine and optic righting reflexes are important in total integration of movement, initial spontaneous movement of the head (dorsiflexion) results as a fragment of the body righting reflex acting on the head determined by contact with the anterior trunk. Even at birth short-lived erect vertical posture of head, trunk and legs may obtain as a transient positive supporting response, which becomes more facile as development continues. Spontaneous extension of the upper limb and prehension develop hand in hand with gradual maturation of the grasp reflex and dexterous use of the hand is acquired only with development of the instinctive grasp response and its concomitant integration with the instinctive avoiding response. The ability to stand alone correlates not only with the full development of the positive supporting response, but with development of contact placing and the delicate orientation of the foot to a light tactile stimulus, the instinctive grasp response of the foot.

In the patient with double athetosis voluntary motor activity is arrested at an early stage. Both in these patients and the normal infant the phenomenon of athetosis can be shown to result from disequilibrium between the grasp reflex and the avoiding response. Associated movements and mass reflexes have an identical basis in the neck and labyrinthine reflexes. With continuing sensory-motor maturation (integration) there is a corresponding improvement in voluntary movement in the infant. We have noted certain improvement in motor function also in patients with double athetosis and have noted that it follows a similar, although obviously not wholly perfect integration of reflex mechanisms. Such may take many years, but with more effective balance of grasping and avoiding reactions, not only does athetosis diminish but voluntary use of the limb improves. With

diminishing intensity of the kinetic-labyrinthine response voluntary limb adduction is possible and with partial integration of the righting reflexes, improvement in head and trunk control occurs.

It is these features of integration which are lacking in the patient with double athetosis, so that the motor deficit in double athetosis results from a defect in maturation or integration of sensory-motor mechanisms together with corresponding hypertrophy of infantile responses.

Information relative to securing reprints of this study may be had by checking the Reader Service column on page iv of this issue.

Seminar in Rehabilitation

PLACE: **Burke Foundation Rehabilitation Center**
785 Mamaroneck Avenue
White Plains, N. Y.

TIME: Ten consecutive Monday afternoons
1:00 to 5:00 P.M.
February 13 to April 10, 1961

APPLICATION: Applications should be forwarded to
Edward J. Lorenze, M.D.
Medical Director

OPEN TO: The seminar is open to individuals in the following fields: Physical Therapy, Occupational Therapy, Nursing, Social Work, Clinical Psychology, Counseling Psychology, Rehabilitation Counseling, Speech and Hearing Services and Special Education.

The seminar will present an integrated and coordinated multi-disciplinary approach to rehabilitation evaluations of children and adults with physical disabilities.

Follow-up Survey Study of a Group of Elderly Above-Knee Amputees

Burton J. Wolters, A.B.
Detroit

● Rehabilitation of an elderly above-knee amputee involves much more than supplying that person with a prosthesis. The absence of one or both lower extremities is but a part of the changes which have developed in such individuals with the course of the diseases which led up to the amputation. Some geriatric amputees maintain a high degree of resourcefulness and require little more than the provision of a prosthesis to regain physical and economic independence, but such cases are rare. As a rule, elderly above-knee amputees constitute a problem group to successfully rehabilitate because of the unique problems of this age group which complicate and even hinder rehabilitation altogether. The factor of age by itself, however, is not of great importance to consider as a problem when the prescription of a prosthesis is involved. This study is directed toward defining more specifically these and related suppositions on the basis of experience with a group of elderly above-knee amputees who had received some help from the Rehabilitation Institute of Metropolitan Detroit during the past few years. Tables are included showing the distribution of the amputees as to sex, race, age, diagnosis, type of amputation, age of those amputees who were advised against prosthesis, civil status of amputees, financial status, functional classification, findings as to use of prosthesis and effect of age on functional classification.

Rehabilitation of an elderly above-knee amputee involves much more than supplying that person with a prosthesis. The absence of one or both lower extremities is but a part of the changes which have developed in such individuals with the course of the diseases which led up to the amputation. Some geriatric amputees maintain a high degree of resourcefulness and require little more than the provision of a prosthesis to regain physical and economic independence, but such cases are rare. As a rule, elderly above-knee amputees constitute a problem group to successfully rehabilitate because of the unique problems of this age group which complicate and even hinder rehabilitation altogether. The factor of age, per se, is not of great importance to consider as a problem. Consideration of the pathogenesis of the entire process leading toward amputation will more likely give an accurate understanding of the factors which inhibit satisfactory rehabilitation.

The elderly amputee typically represents far advanced stages of a long standing, gradually debilitating disease. Amputation of one or both lower extremities was the effort of last resort to manage the disease in that part of the body. Before the time of amputation these persons had gradually undergone decreasing independence and had slowly developed increasing dependence on others, emotionally, physically and economically. To them, therefore, amputation signifies the final blow fate has dealt them to render them completely dependent on others. Psychologic aspects of their disability often are deep seated because of the long term of development; and these constitute real and frequently insurmountable problems in rehabilitation efforts.

Physiologic aspects of the disease itself must be given special consideration in the total rehabilitation effort. In the elderly, amputation most frequently results from a generalized disease process in contradistinction to other causes in younger age groups. Amputation, therefore, does not solve the problem of the underlying disease, but only of one complication of the disease. Other complications of the disease must surely be reckoned with in the process of rehabilitation of these individuals.

Many of the elderly above-knee amputees suffer from multiple diseases. Some of these diseases may be discrete but more often there is a great deal of interaction with one another. Whether discrete or not, they all contribute to reducing the physiologic reserves of the individual resulting in frailty in general and disability locally.

As a result of all these factors not all geriatric amputees will be successfully rehabilitated, to physical, social and economic independence. In some cases, to provide a prosthesis would be a serious mistake, taxing the limited physiologic reserve capable of handling such a device. In other cases there is a high degree of failure to achieve any benefit from a prosthesis even after the benefits were carefully evaluated before the prosthesis

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Senior Medical Student at Wayne State University College of Medicine, Detroit, Mich., and Research Fellow of the National Foundation.

was prescribed and after tremendous effort was expended to rehabilitate the patient. Other patients achieve a variable degree of benefit from their rehabilitation. Few patients achieve highly satisfactory rehabilitation.

The present study is directed toward defining more specifically the truth of the above suppositions on the basis of experience with a group of elderly above-knee amputees who had received some help from the Rehabilitation Institute of Metropolitan Detroit during the past few years.

The Present Study

The present study was undertaken with the support of the National Foundation as a fellowship grant to senior medical students.

Cases. Since 1951, when the Rehabilitation Institute of Metropolitan Detroit was founded, until the beginning of 1959 a group of 75 above-knee amputees over the age of 50 had received some special consideration at the Institute to rehabilitate them. The age of 50 was chosen arbitrarily to define limits of the study. In this group of 75 there were 55 males and 20 females (table 1). Fifty-three persons were of the white race and 22 were of the Negro race (table 2).

The majority of the patients were between the ages of 50 and 65 at the time they were referred to the Institute. The oldest person referred was 79 years of age (table 3).

Diagnostic grouping is illustrated in table 4. Because of inaccurate and incomplete records kept in the early history of the Institute no distinction has been made between gangrene of the lower extremity due to arterial thrombosis, embolism, Buerger's disease, and arteriosclerosis. All of these have been categorized as "peripheral vascular occlusive disease." Diabetes mellitus has been kept separate because such diagnosis is more accurate and significant. In five cases the diagnosis is unknown because of incomplete records. Trauma alone, without osteomyelitis being a factor, is listed separately and accommodates four cases of the entire group of 75 amputees.

Table 1: Sex Distribution of 75 Geriatric Amputees

Sex	Number	Per Cent
Male	55	73
Female	20	27
Total	75	100

Table 2: Racial Distribution of 75 Geriatric Amputees

Race	Number	Per Cent
White	53	71
Negro	22	29
Total	75	100

Table 3: Age of 75 Geriatric Amputees

Age Group	Number	Per Cent
50-54	21	28
55-59	12	16
60-64	16	21
65-69	16	21
70 and over	10	14
	75	100

Table 4: Diagnostic Grouping of Elderly A-K Amputees

Diagnosis	Number	Per Cent
Diabetes Mellitus	25	33
Peripheral Vascular Occlusive Disease	23	31
Trauma	4	5
Osteomyelitis	10	13
Lues	2	
Varicose ulcers	2	
Tumors	2	11
Severe Burn	1	
Frostbite	1	
Unknown	5	7
Total	75	100

The types of amputations are summarized in table 5.

Table 5: Type of Amputation

	No. of Cases	Type	Number	Per Cent
Single	61	right	30	40.0
		left	31	41.3
Bilateral	12	a-k	7	9.3
		a-k/b-k	5	6.7
Unknown	2		2	2.7
Total	75		75	100.0

The single amputees constituted 81 per cent of all the cases while the bilateral amputees constituted about 16 per cent of the cases.

After evaluation by the Institute staff 15 patients, or 20 per cent of the study group, were advised against using a lower extremity prosthesis. The age of

these patients is shown in table 6. Age in itself is not a factor to inhibit the prescription of a prosthesis, because all age groups are represented approximately equally according to this chart. Six of the 12 bilateral amputees were found in this group of amputees. Four of these were over the age of 65. Of the six bilateral amputees, however, who were prescribed lower extremity prostheses the age group distribution was nearly identical as in the other group of six, so bilateral amputation, per se or in conjunction with age, does not enter into the decision of whether to prescribe prostheses or not. The advanced disease in other parts of the body was explicitly the cause of poor rehabilitation prognosis in 13 of the 15 cases. A severe psychosis was the main factor in another case. No apparent cause for refusal was discovered in another's case.

Table 6: Age of Amputees Who Were Advised Against Prosthesis

Age Group	Number	Per Cent
50-54	2	13
55-59	4	27
60-64	3	20
65-69	4	27
70 and over	2	13
Total	15	100

Methods. Our intent was to conduct a follow-up survey study of this group of 60 remaining cases of elderly above-knee amputees, inasmuch as most of them had not returned to the Institute following their first series of visits. None currently were receiving therapy or training at the Institute at the time the study was carried out. Data forms were assembled to record information about the amputee's general clinical history and general physical examination, the examination of the stump and contralateral limb, the description and checkout of the prosthesis, and the description and checkout of the performance of the amputee while wearing the prosthesis. All persons studied were visited by myself in their homes where they were interviewed and examined when necessary. A special "follow-up clinic" was established at the Institute and the amputees were urged to appear before the staff of the Institute for re-evaluation. The staff was composed of two physiatrists, an orthopedic surgeon, social workers, and various therapists and nursing personnel. Provisions for further therapy and training were decided at these clinics.

Results of Survey

Of the 60 persons who had received prostheses, 44 persons were able to be reached with one form of followup contact or another. Sixteen persons could not be immediately contacted and are considered lost to the study. Due to the limited time available special efforts to locate these cases could not be carried out. The study at this stage is incomplete, therefore. Thirty-one patients were contacted by myself in their homes where the interview and initial physical examination were carried out. Eleven patients were found to have expired since their training and therapy at the Institute. Six persons had moved to other areas and letters sent to their last known address resulted in a followup of but two more persons; one had expired and the other filled out a questionnaire form. Table 7 summarizes the division into the groups studied.

Table 7: Study Groups of 75 Geriatric Above-Knee Amputees

Group	Number	Per Cent
Patients contacted	32	43
Patients not given prosthesis	15	20
Patients who had died	12	16
Patients lost to study	16	21
Total	75	100

Of the 32 persons successfully contacted in followup, 24 were males and eight were females; 22 were of the white race and 10 were Negro. All were living at home. Institutionalized patients were in the "lost" group apparently. The civil status of these amputees is shown in Table 8.

Table 8: Civil Status of 32 Contacted A-K Amputees

Status	Number	Per Cent
Married	21	66
Mate deceased	7	22
Separated	2	6
Divorced	1	3
Single	1	3
Total	32	100

Age of these patients is shown in table 9:

Table 9: Age of 32 A-K Amputees Contacted

Age Group	At Time of Survey		At Time of Referral	
	No.	Per Cent	No.	Per Cent
50-54	5	15.5	12	38
55-59	7	22.0	3	9
60-64	5	15.5	6	19
65-69	6	19.0	7	22
70 and over	9	28.0	4	12
Total	32	100.0	32	100

The financial status of these 32 patients is shown in table 10.

Table 10: Financial Status of 32 A-K Amputees

Status	Number	Per Cent
Working	8	25
Old age benefit	14	41
Aid to disabled	5	16
Supported by family	3	10
Supported by own savings	2	8
Total	32	100

To evaluate the degree of disability which these people showed, or in some cases, to evaluate the degree of rehabilitation achieved with the use of the lower extremity prosthesis the classification of Rusk[1] was modified and used as a diagnostic tool. The criteria for the functional classification are as follows:

Class 1. Full Restoration. The individual has been functionally restored to the equivalent of normal; he is essentially a non-disabled individual who can perform his former job with no restrictions and who is completely competitive in sports and former social life.

Class 2. Partial Restoration. The individual is completely functional with his prosthesis and wears his limb all day. He is able to work but he might have to make changes in his job if his former occupation has been too strenuous. He can dance but doesn't dance as much as formerly. He does not walk as far as he used to and there are some activities such as tennis and golf in which he no longer participates but he is a functioning individual who can live an acceptable and full life.

Class 3. Self-Care Plus. The individual is disabled but yet is capable of doing everything for himself on a personal basis and more. He might be able to work if he can obtain the kind of job that does not require too much standing and walking. He no longer dances, carries weights, walks distances but he is a functioning individual who can live in the home and discharge his responsibilities to his family. He wears his prosthesis more of the waking hours than he does not wear it and it is of benefit to him.

Class 4. Self-Care Minus. The individual in this category is better off with a limb than without one though he may use it only for cosmetic purposes. He wears it only for short periods at a time and may use it only for intervals of a few weeks, not wearing it at all for alternate intervals of shorter or longer duration. His best achievement falls somewhat short of taking care of his needs and he requires help from others. He cannot go up and down stairs without assistance of another person or of crutches. He relies on wheelchairs and/or crutches a great deal of the time. He does not go out alone because he might not be safe. He is able to live at home with his family if he has the prosthesis whereas he might require institutionalization if he did not have the prosthesis, because he would require too much help from other people.

Class 5. Not Feasible. This individual does not wear his limb at all and considers it a burden. He is better able to function with crutches and a wheelchair, and may not be too severely disabled if he becomes proficient with these appliances.

Table 11 illustrates the functional classification of the 32 elderly above-knee amputees who were contacted in follow-up, after each was evaluated according to the criteria listed above.

Table 11: Functional Classification of 32 A-K Amputees

Class	Number	Per Cent
1	0	0
2	8	25
3	8	25
4	6	17
5	10	33
Total	32	100

None of the patients contacted were judged to merit class 1 on the basis of the criteria listed above. Fifty per cent of the patients contacted were clearly deriving benefit from their prostheses.

The other 50 per cent were not wearing the prosthesis at all or used it for short periods each day, then hardly benefiting from the limb except for the cosmetic value (table 12).

Table 12: Survey Findings as to Use of Prosthesis

Category	Number
Wearing prosthesis full day	16
Using crutches mainly	10
Using wheelchair mainly	6
Confined to bed	0
Total	32

Table 12 recapitulates table 11 but there were persons in both classes 4 and 5 who depended more on crutches than on the wheelchair and the same situation was found in those six individuals using a wheelchair more than crutches. Only half of those wearing the limb a full day used it efficiently. These were all employed. The other half used the limb, relying to a great degree on walking canes. These walked slowly and not any great distances. They all were unemployed, performing petty tasks about their homes and all complained about improper fitting of their prosthesis. Those in class 2 had complaints but they were fewer and of less consequence to the amputees. The patients using crutches mainly or wheelchair mainly to assist in caring for themselves were generally more debilitated than those using the prosthesis, although this does not hold true in every case. Two cases who were apparently strong enough physically to efficiently use a prosthesis seemed to prefer crutches to any other prosthetic device, though much effort was expended to help them adapt to the artificial limb.

The age distribution correlated with the functional classification is shown in table 13.

This table shows that age, per se, has little to do with the degree of rehabilitation achieved by geriatric amputees, in that all age groups are represented in nearly every class, exclusive of class 1 of course. One woman, age 69, achieved the highest degree of rehabilitation of all those amputees interviewed successfully in the followup. Incidentally, her amputation resulted from trauma, a significant feature. Another patient, age 53, was the example of the poorest results. He was a severe diabetic and appeared much older than his chronologic age.

The physiologic age of the amputees repeatedly was the outstanding feature associated with success or failure. No quantitation of this correlation was achieved however.

Scrutiny of the amount of training in the usage of the lower limb prosthesis revealed little differences in those of class 1 and class 5. There was much difference when consistency of the training periods was correlated with the two groups. Those classed in group 5 were much more haphazard in their appearance for gait training appointments but this reflects the fact that complicating physiologic abnormalities were operating already at the time rehabilitation was started.

Complaints about the fit of the prosthesis, pain in the stump, poor attention given by Institute personnel were more common in those who failed to benefit satisfactorily from the rehabilitation effort. Although no precise psychologic evaluation was performed a distinct impression of rather severe emotional disturbances was noted in eight of 16 amputees who were classed in classes 4 and 5.

Table 13: Effect of Age on Functional Classification

	Age Groups				
Class	50-54	55-59	60-64	65-69	70 and Over
1					
2	54	55, 57, 56	64	65, 69, 65	
3	54	55, 59	61, 63		71, 80, 71
4		57	64	65	76, 72, 74
5	53, 54, 50	55	64	69, 66	71, 77, 74

Numbers in blocks are the ages of the 32 amputees contacted at the time of the study.

Severe generalized disease or multiple diseases, extensive enough to restrict the degree of rehabilitation, were present in 14 of 24 amputees who might otherwise have achieved greater levels of performance. Of the 10 who remain who might have achieved a greater level of performance, six were given a functional classification of 3 and might have achieved a level of 2 if a necessity to work were present. All were receiving retirement or disability compensation. Two amputees of this group were in class 4 and two were in class 5. Again, lack of incentive and need to function at a higher level was prominent in this respect.

Study of the eight persons who were working showed that all were under the age of 65 except one woman, age 69, who was still working as a secretary. All were working at former occupations though slight changes in specific duties were noted in nearly every case. There were seven males and one female in this group. All except the woman amputee had rather outstanding gait defects. Trauma, or trauma resulting in osteomyelitis, was the factor for which amputation was required in four of the eight cases. Peripheral vascular occlusive disease was the factor in the other four patients, two of whom were diabetics. Four of the eight persons had purchased the limb with their own finances. There were no persons using crutches primarily or wheelchair primarily who were working outside the home.

Summary

1. Seventy-five cases of above-knee amputees, over the age of 50, were studied as a follow-up survey of results achieved by the Rehabilitation Institute of Metropolitan Detroit during the last few years.

2. Diabetic gangrene was the most frequent cause for amputation; vascular disease closely followed diabetes; and trauma, with and without osteomyelitis, was the third most frequent cause.

3. Single above-knee amputations were most frequently encountered.

4. One-half of the bilateral amputees was advised against obtaining prostheses while in the other half only one was able to use his devices, then only with a great deal of effort.

5. Twenty-one per cent of the cases could not be contacted for follow-up study.

6. Twenty-one per cent of the persons contacted were found to be using their lower extremity prosthesis to a distinct advantage to themselves; half of these were employed at a full time occupation.

7. Twenty-one per cent of the persons contacted were found to be using their prosthesis little if at all.

8. Thirty-six per cent of the cases had either been refused a prosthesis or are known to have died.

9. Ten per cent of the persons are working outside the home although 50 per cent of all persons contacted were under the age of retirement (65) at the time the study was conducted.

10. Of the eight persons who were working outside the home, all were using the prosthesis; all were working at former occupations with minor adaptations to their disability, and all remained off the job from nine months to 16 months at the time their disability occurred.

Conclusions

Outstandingly successful rehabilitation of elderly above-knee amputees is very rare but prosthetic devices should be prescribed to most persons, even if the degree of benefit is small. Generalized disease and multiple diseases accounts for most of the failure to achieve a good level of rehabilitation and, for this reason, the patients should be closely evaluated before prescription. In some of these the use of a lower extremity prosthesis would be very dangerous. Psychologic factors also were a prominent feature of many failures. Age, per se, does not determine the degree of success which might be anticipated from rehabilitation efforts but physiologic age certainly does. Most persons are able to live at home and take care of their physical needs, regardless of whether they use a prosthesis primarily, crutches primarily, or a wheelchair primarily. Emotionally and economically, however, very few achieve a satisfactory level of

independence. Perhaps more work is needed in these areas because physical independence is achieved more or less on the patient's own resources rather than on any particular rehabilitation effort.

Reference

1. Rusk, Howard A.: Rehabilitation Medicine, St. Louis, C. V. Mosby Company, 1958, pp. 354-356.

Information relative to securing reprints of this study may be had by checking the Reader Service column on page iv of this issue.

DEPARTMENT OF PHYSICAL MEDICINE AND REHABILITATION

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survey of selected literature

JOURNAL OF PHYSIOLOGY. *Vol. 151, April 1960.*

◇ **The Acetylcholine Sensitivity of Frog Muscle Fibers after Complete or Partial Denervation. R. Miledi. pp. 1-23.**

The sensitivity of isolated frog sartorius muscle fibers to acetylcholine was measured by the degree of depolarization recorded by intracellular microelectrodes. Completely denervated individual muscle fibers and single fibers in which some but not all end plates were denervated were studied. The area of membrane sensitive to acetylcholine increased after complete denervation and involved the whole fiber surface by the end of 10 weeks. The original end plate region remained the most sensitive area to acetylcholine but was no more sensitive than end-plate areas of innervated fibers.

Membrane potentials were recorded simultaneously from a denervated and an innervated end plate of the same muscle fiber. At the innervated end plate, potentials were normal in frequency and amplitude. At the denervated end plate, potentials were normal at first, disappeared after the first few days after nerve section, and reappeared a few days later.

When acetylcholine was diffusely applied to partially denervated single fibers, the denervated end plate was more sensitive than the innervated end plate. Sensitivity at the innervated end plate to locally applied acetylcholine was no different than in normal fibers.

The results indicate that motor nerve exerts a direct restraining action on the chemo-sensitivity of muscle, and that after denervation supersensitivity is caused not by muscle inactivity, but by removal of the neural influence. Furthermore, the supersensitivity is not an increase in sensitivity of the receptors themselves but an increase in the size of the chemo-sensitive membrane area.

◇ **Mechanism of the After-Potential Production in the Giant Axons of the Cockroach. T. Narahashi, and T. Yamasaki. pp. 75-88.**

The action potential of the giant axons of the cockroach was studied with intracellular microelectrodes to study the mechanism of production of the negative after-potential. The potentials were studied under several potassium and calcium external concentrations.

Raising external potassium concentration decreased resting potential, action potential height and the heights of the positive phase and negative after-potential. During repetitive stimulation, negative-after potentials added linearly. The decay of the negative-after potential was described by a single exponential, and raising external potassium concentration decreased the time constant.

Raising external calcium concentration, increased the negative-after potential and lengthened the decay time constant.

The results indicate that the negative-after potential may be due to an accumulation of released potassium in the immediate vicinity of the nerve membrane, and that the increase was about 2.0 mM.

The chloride conductance of frog skeletal muscle. *Hutter, O. F., and D. Noble. p. 89.*

Alteration of spinal reflexes by interaction with suprasegmental and dorsal root activity. *Kuno, M., and E. R. Perl. p. 103.*

The production of rumen and reticulum contractions in decerebrate preparations of sheep and goats. *Titchen, D. A. p. 139.*

Potassium chloride movement and the membrane potential of frog muscle. *Adrian, R. H. p. 154.*

The relationship of the oxygen consumption to the contraction of the cat papillary muscle. *Lee, K. S. p. 186.*

THE NEW ENGLAND JOURNAL OF MEDICINE. *Vol. 263 (No. 1) 1960.*

◇ **Clinical Evaluation of the DNA Bentonite Flocculation Test for Systemic Lupus Erythematosus. D. Kayhoe; J. Nasou, and J. Bozicevich. pp. 5-10.**

This report is a clinical evaluation of the dexoxyribonucleic acid (DNA) bentonite flocculation reaction as a test for systemic lupus erythematosus.

To perform the test a suspension of bentonite particles coated with purified, highly polymerized calf-thymus DNA is exposed to twofold dilutions of heat-inactivated test serum on ringed glass slides. A positive reaction is indicated by flocculation estimated under the low power of the microscope through a range of + to ++++. The results are expressed as the dilution in which + or greater flocculation is observed.

All 13 of the patients with active lupus erythematosus had positive DNA bentonite flocculation tests. Of this group 11 had positive L.E.-cell preparations at the time of testing.

Of the 12 patients with lupus in remission only two who had received steroid treatment and one with a spontaneous remission had positive DNA tests, and these were in low titer. All had present or past positive L.E.-cell preparations.

A close parallelism exists between active systemic lupus and a positive DNA test and lupus in remission and a negative DNA test. Thus, several patients showed stepwise reductions in titer and ultimately negative DNA flocculation tests after the disease went into remission. In contrast the L.E.-cell preparation tended to remain positive longer and was positive more often in the absence of clinical manifestations.

Seven patients with rheumatoid arthritis and positive L.E.-cell preparations had negative DNA bentonite flocculation tests. Eight hundred and nineteen other patients and 133 normal employees had negative DNA bentonite tests.

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THE NEW ENGLAND JOURNAL OF MEDICINE. *Vol. 263 (No. 1) 1960.*

◇ **Dysphagia and Hypertrophic Spurring of the Cervical Spine. D. Hilding and M. Tachdjian. pp. 11-14.**

Asymptomatic hypertrophic spurs of the anterior margin of the cervical vertebras are common. In the literature, 36 cases have been reported in which dysphagia was caused by hypertrophic spurring of the cervical spine.

Sixty per cent of the cases were males. The mean age was 60 years. The most common location of osteophytosis was the third to fourth, fourth to fifth and fifth to sixth cervical vertebras.

Difficulty in swallowing, particularly of solid food, was the most frequent complaint, but the patients also complained of painful swallowing, as well as foreign-body sensation, cough, hoarseness and constant rasping or urge to clear the throat.

On examination the mass is often easily visualized by routine examination of the throat with a tongue depressor or mirror. Sometimes endoscopy is necessary. Palpation shows it to be a hard, smoothly rounded, nonmovable mass projecting into the pharynx from behind. Roentgenographic examination shows a marked spurring of the anterior edges of the vertebral bodies, with the formation of a mass projecting into the pharynx.

Histologically, the spur has the structure of hypertrophic bone. The only treatment that seems to be accepted is surgical excision of the offending mass. The osteophytes that have been excised have been removed through an external approach. It is difficult to be certain of the prognosis of this condition.

This paper reports on three cases, one of which was successfully treated by surgical excision of the osteophyte.

Familial recurring polyserositis simulating acute surgical condition of the abdomen. *Nixon, R., and R. Priest. p. 18.*

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THE NEW ENGLAND JOURNAL OF MEDICINE. *Vol. 263, July 28, 1960.*

◇ **Plastic Surgery: The Hand. B. Cannon, and E. Peacock. pp. 184-189.**

The purpose of this review is to summarize a few of the important advances in surgery of the hand.

Three phases of activity are recognized in Dupuytren's disease of the palmar fascia. The first is the proliferative stage, manifested by one or more subcutaneous nodules that are microscopically quite cellular. These cellular masses replace the subcutaneous fatty tissue and become attached to the skin. There is no contracture at this stage and no indication for surgical intervention. The second stage is characterized by a linear orientation of the cells in the nodule, which become more collagenous and less cellular. A cord usually develops proximal to the nodule. The cord lying in the line of stress becomes hypertrophic from tension as contraction progresses within the nodule. The fibrous bands extending from the hypertrophied bands and the nodule produce distortions of the fingers because of attachments to skin, palmar aponeurosis, tendon sheaths and joint capsules. It is in the early phases of this second stage that surgical excision is most effective. In the final stage the nodule disappears, leaving only acellular fibrous cords. Varying degrees of contracture persist, and changes in the joints and periarticular tissues often become irreversible. Surgical excision of part or all of the palmar fascia is the only treatment that will have a lasting effect. Motion of the fingers and even the metacarpal phalangeal joint can be started immediately.

The carpal tunnel syndrome is characterized by nocturnal aching, burning and pain in the median-nerve distribution, often precipitated by a change or increase in physical activity of the hand. It may progress to total anesthesia and atrophy of the thenar muscle. When the wrist is held flexed for approximately sixty seconds there is usually a prompt increase in the numbness, tingling and pain in the distribution of the median nerve. The treatment of this condition is surgical.

In chronic rheumatoid arthritis surgical reconstruction should be undertaken promptly if the deformities are progressing. The ulnar drift caused by a subluxation of the long extensor tendon to the ulnar side of the metacarpal head is correctable by a number of technics.

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THE NEW ENGLAND JOURNAL OF MEDICINE. *Vol. 263, July 14, 1960.*

◇ **Relapsing Polychondritis. C. M. Pearson; H. M. Kline, and V. D. Newcomer. pp. 51-58.**

Relapsing polychondritis is a distinct clinical and pathological entity. Its etiology and pathogenesis are unknown, and its relation to one of the connective-tissue diseases or to the cartilaginous dystrophies is indistinct at present. There is a nearly uniform pattern of involvement of multiple cartilages, those of the external ears, nasal septum, joints and larynx predominating. Inflammation of the eyes often occur. The disease develops in both sexes and in all ages. In its most common form the clinical picture is one of recurrent bouts of inflammation of cartilage. Attacks are followed by spontaneous or induced remissions. Usually after several acute bouts of inflammation the cartilage collapses and is replaced by connective tissue. Serious complications of relapsing polychondritis include various degrees of destructive arthritis, deafness, blindness and the development of a flail chest wall. The clinical laboratory has contributed almost nothing to the diagnosis of polychondritis. The etiology of the disease is unknown. The articular manifestations are remarkably similar to certain forms of rheumatoid arthritis. Wegener's granulomatosis, or pathergic granulomatosis, is a syndrome that shows superficial similarity to polychondritis. Reiter's syndrome also has some resemblance to polychondritis. Therapy in relapsing polychondritis is confined at the present time to the continuous use of corticosteroids.

Two cases of relapsing polychondritis are described in detail, and 10 cases previously described in the literature are briefly summarized.

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THE NEW ENGLAND JOURNAL OF MEDICINE. *Vol. 263, July 21, 1960.*

The approach to patients with functional disorders. *Tumulty, P. A. p. 123.*

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THE NEW ENGLAND JOURNAL OF MEDICINE. *Vol. 263, July 28, 1960.*

Aseptic management of catheter drainage *Desautels, R. E. p. 189.*

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AMERICAN JOURNAL OF THE MEDICAL SCIENCES. *Vol. 240, Aug. 1960.*

◇ **Esophageal Reflex Origin of Myocardial Infarction. H. G. Roesler. pp. 159-162.** Previous work by various authors had shown that electrocardiographic changes followed alteration of the temperature of different parts of the heart in experimental animals. Changes had been noted in man after drinking ice-water. In particular, one previous investigator had found that this procedure caused conspicuous changes in the T wave of the electrocardiogram. The author describes the histories of four patients seen in a period of about one year in whom the onset of myocardial infarction closely followed the ingestion of ice-water or hot food or drinks. He concludes that if subsequent work should sustain this association of myocardial infarction with ingestion of very hot or cold food or drink, precautionary avoidance of these acts should be considered.

◇ **The Digital Rheoplethysmogram During Asian Influenza. J. J. Walsh, and G. E. Burch. pp. 163-170.**

The authors examined the digital rheoplethysmogram in 20 patients with Asian influenza. Follow-up studies were carried out during and after recovery from the illness. The technics previously described by Burch were used in the study. Fifteen of the patients revealed peripheral vasoconstriction and reduced digital flow at the height of illness. Four patients demonstrated no significant change in digital flow while one, whose illness was severe and complicated by coincident staphylococcic pneumonia, showed an increased digital blood flow during the acute phase of the disease. All patients exhibited essentially normal flow rates upon recovery. The authors believe that the observed vasoconstriction may have been a manifestation of the presence of fever or a shunting of blood to the vital organs.

The status of the adrenal gland in the asthmatic patient. *Kass, I., and S. Appleby. p. 213.*

Progress of medical science section — urinary diversion. *Crowley, R. T., and L. L. Swigart. p. 232.*

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ARCHIVES OF NEUROLOGY. *Vol. 3, Aug. 1960.*

◇ **Motor Unit Action Potential Parameters in Human Newborn Infants. Romualdo Jose do Carmo. pp. 136-140.**

Motor unit action potentials were studied in normal human newborn infants, 12 hours to seven days of age. Studies were performed in the quadriceps femoris and the tibialis anterior muscles using concentric and multielectrodes. The form of action potentials was the same as those of normal adults, but there were nine per cent and 16 per cent polyphasics in the quadriceps femoris and the tibialis anterior, respectively. The amplitudes ranged from 100 microvolts to 1,600 microvolts and 100 microvolts to 1,500 microvolts in the quadriceps femoris and the tibialis anterior muscles, respectively. The duration of the action potentials ranged from two to 10 and 2.5 to 10.5 msec. for the quadriceps femoris and the tibialis anterior, respectively. These durations were 17 per cent to 26 per cent lower than the results reported by Petersen and Kugelberg for the adult first dorsal interosseus and biceps brachii. The diameter of the motor units ranged from two to 10 mm., assuming that any potential between bipolar leads 1.6 mm. apart must be due to differentially active tissue within that distance. A comparison is made between the amplitudes found in the infant and in the adult stating that the infant amplitudes are 66 per cent higher than the adults, but the comparison is made from studies performed on the biceps brachii in the adult.

◇ **Inhibition of the Muscle Spindle Discharge by Ventrolateral Thalamic Stimulation. J. Stern, and A. Ward, Jr. pp. 193-203.**

The effect of stimulation of the ventolateral nucleus of the thalamus of the cat upon muscle spindle discharge was studied in 18 cats anesthetized with pentobarbital sodium or diallylbarbituric acid intraperitoneally. The right hindlimb was denervated except for the gastrocnemius and soleus muscles. Fixation of the right hindlimb was obtained by metal pins in the femur, pelvis and tibia; the gastrocnemius tendon was attached to a strain gauge. Dorsal root fiber recording of single spindle discharges from L7 or S1 were recorded on magnetic tape and later photographed when displayed on an oscilloscope. Intracerebral stimulation was performed with bipolar concentric needle electrodes. The characteristic effect of stimulation of the nucleus ventralis lateralis was profound inhibition of the contra-lateral muscle muscle-spindle discharge. The discharge could be abolished for as long as 50 seconds with a five second cps. volley of msec. square waves. There was also temporary inhibition of the spindle discharge during 2/sec. stimulation of the nucleus ventralis lateralis. Subthreshold stimulae of 15 volts had no effect

upon the rate of fire and 50 volts gave an inconsistent response while 90 volts appeared to be supramaximal giving consistent inhibitions. If the gastrocnemius muscle were stretched one centimeter the afferent spindle discharge increased in frequency and a larger threshold stimulus was necessary to produce inhibition. Ablation of pericruciate cortex and the head of the caudate nucleus silenced the muscle spindle even during stretch of the gastrocnemius while ablation of the pericruciate sensorimotor cortex eliminated the inhibitory effect produced by stimulation of the nucleus ventralis. The authors present a brief discussion of the gamma efferent and muscle spindle system and also discuss the possible relation of their findings in relation to the rigidity and akinesia of Parkinsonism.

Neonatal jaundice and mental retardation. *Zuelzer, W. p. 127.*

Observations on selective brain cooling in dogs. *Lourie, H.; T. G. Holmes; W. Weinstein; H. G. Schwartz, and J. L. O'Leary. p. 163.*

Early descriptions of aphasia. *Benton, A. L., and R. J. Joynt. p. 205.*

AMERICAN JOURNAL OF PHYSIOLOGY. *Vol. 198, June 1960.*

◇ **Similarity of Cardiovascular Responses to Exercise and to Diencephalic Stimulation. O. A. Smith, Jr.; R. F. Rushmer, and E. P. Lasher. pp. 1139-1142.**

The authors found the classical explanation of the cardiovascular response to exercise inadequate to explain the results of recent experiments. They undertook, in the present work, to demonstrate that high levels of the central nervous system may be more important than medullary reflexes and peripheral mechanisms. They have again employed chronic canine preparations in which mechano-electrical transducers were implanted within the chambers of the heart and great vessels to measure intracardiac pressures, heart rate and cardiac diameter. After recovery from the first operation, the dogs were trained to exercise on a treadmill. Subsequently with the aid of stereotaxic placement, electrodes were either acutely or chronically implanted in the diencephalon. In the acute preparations, under chloralose anesthesia, a general mapping of diencephalic stimulation was carried out. Preliminary experiments yielded definite stereotaxic coordinates. Cardiovascular responses were correlated with the corresponding stimulation sites by the production of electrolytic lesions in the brain. In the chronic preparations, an electrode was permanently stereotaxically placed along a single track which had proved to yield interesting cardiovascular responses in the acute experiments. Results showed that similar cardiovascular responses were produced by both stimulation and exercise when stimulation was carried out in the H_1 and H_2 fields of Forel, and in the periventricular gray matter of the third ventricle. Stimulation of these areas, particularly the H_2 field of Forel, frequently produced running movements in the chloralose-anesthetized animal. In some of these animals the typical cardiovascular response obtained even after the administration of the muscle blocking agent decamethonium had eliminated all voluntary muscular activity. The authors point out that these data fit in with the previously observed cardiac responses in anticipation of exercise.

◇ **Dependency of Oxygen Consumption of Skeletal Muscle on Number of Stimuli During Work in the Dog. J. T. Fales; S. R. Heisey, and K. L. Zierler. pp. 1333-1342.**

The work reported in this paper was undertaken as one step in a study of the aerobic recovery processes of mammalian skeletal muscle with functioning circulation after activity. Mongrel dogs under pentobarbital anesthesia were employed. The gastrocnemius-plantaris muscle group was exposed and its venous drainage was isolated for flow measurement and periodic sampling. Clotting was prevented with manuronate and constant arterial oxygen content was maintained by artificial respiration. The tension and shortening produced by the isolated muscle group was measured by a lever system attached to the severed calcaneus with the Achilles tendon attached. Trains of supramaximal pulses of 3.5 msec. duration were delivered to the sciatic nerve by an electronic stimulator. The delay time between trains of pulses was always 1.5 sec. The extra oxygen consumption elicited by the various series of contractions was studied as a function of the following parameters: muscle load, frequency and duration of the trains of stimuli, number of tetanic contractions, and isotonic versus isometric contraction. The only parameter found to be linearly related to the extra oxygen consumption was the number of stimuli per contraction (at sufficiently low rates of stimulation — 18 per sec.). The authors conclude that knowledge of the local oxygen consumption alone is insufficient evidence upon which to appraise the metabolic activity. They aver that much more detailed information on the metabolic processes is needed in order to explain adequately the results of these experiments.

Lymphatics in genesis of ascites in the rat. *Raybuck, H. E.; T. Weatherford, and L. Allen. p. 1207.*

Hypothalamus and respiratory minute volume. *Redgate, H. S. p. 1304.*

AMERICAN JOURNAL OF PHYSIOLOGY. *Vol. 199, July 1960.*

◇ **Induction of Hypertension in the Frog by Bilateral Nephrectomy. E. F. Grollman, and A. Grollman. pp. 19-21.**

The reason behind the work reported was to ascertain whether hypertension could be induced in frogs by procedures known to cause this pathology in higher animals. Experiments were performed on three species of frogs commonly used in the laboratory. Nephrectomy was chosen as the experimental procedure since this is known to produce classical hypertensive cardiovascular disease in mammals. Winter frogs were subjected to bilateral nephrectomy under urethane anesthesia. The adrenals were unavoidably removed in this procedure. In order to separate the effects of nephrectomy and adrenalectomy, the adrenals were transplanted into muscles in some animals. Survival time following the removal of both sets of organs averaged seven days while that following nephrectomy and adrenal transplantation averaged 16 days. Hypertension was demonstrated following nephrectomy in both types of experiment. In a third series of experiments bilateral ureteral ligation was performed. The animals of this series did not develop hypertension. The authors conclude that nephrectomy was the cause of the observed hypertension. They suggest that the demonstration of the importance of the kidney in maintaining normotension in species as widely separated as amphibians and mammals involves the kidney in some basic mechanism for the control of the cardiovascular system.

◇**Effect of Cardiac Cooling on Coronary Vascular Resistance in Normothermic Dogs. R. A. Hardin; J. B. Scott, and F. J. Haddy. pp. 163-166.**

This investigation was undertaken in an attempt to dissociate the effects of total body cooling from those of cooling only the heart upon the coronary vascular resistance. Previous studies of coronary cooling had involved total body cooling. At surgery, cardiac and systemic circulations were separated and each system was separately perfused with external pumps. Normal body temperature was maintained while the temperature of the heart was controlled with that of the blood perfusing it. The heart was beating but performing no external work. Electrolyte concentrations, pH, electrocardiogram and vascular pressures were monitored while coronary flow was held constant. During cooling the perfusion pressure dropped while during the rewarming the pressure rose. There was a significant lag in the recovery curve. The viscosity of the blood was higher at the lower temperatures. The authors interpret the results as showing an unquestionable drop in vascular resistance. They further exclude other possible causative factors to show that the decreased resistance resulted from an active vasodilation. A sudden drop in resistance accompanied the start of the rewarming of cardiac blood. In spite of attempts to correlate changes in resistance with cation efflux or influx, the limited precision of the electrolyte analyses precluded any positive findings in this area. Vagotomy had no observable effects on the results.

Vascular resistance changes produced by hyperosmotic solutions. *Harvey, R. B. p. 31.*

Affinity of cartilage matrix for calcium. *Thomas, W. C., Jr., and W. C. Pickett. p. 103.*

AMERICAN JOURNAL OF PHYSIOLOGY. *Vol. 199, Aug. 1960.*

◇ **Contractility of Muscle in Solutions of Low Electrolyte Concentration. E. Bozler. pp. 299-300.**

Experiments are described which support and extend the observations of previous investigators on the contractility of smooth muscle in electrolyte-free sucrose solutions. Rings of the posterior fourth of a frog's stomach were employed. After recording the spontaneous repetitive contractions of a preparation, it was placed in isosmotic electrolyte-free sucrose solution. Spontaneous contractions stopped in about five minutes. After varying periods without contraction in the latter solution, motility was restored by the addition of $CaCl_2$ in concentrations as low as 0.5 milli-molar. Magnesium ion failed to restore contractility. Similar results were obtained when the principal solute was glucose or choline chloride.

The author concludes that normal activity of smooth muscle is possible in solutions almost free of electrolytes. He reports observing similar responses from frog skeletal muscle. Normal conducted excitation of skeletal muscle in solutions of sucrose and low Ca^{++} concentration was not obtained. However, local nonconducted excitation occurred at supranormal threshold. The results conflict with the current view that Na^{+} ions are essential in the extracellular fluid for the excitation process. They are consistent, however, with the hypothesis that local excitation of the contractile system is accomplished by means of an intracellular conduction system recently associated with the sarcoplasmic reticulum.

A mechanism by which helium increases metabolism in small mammals. *Leon, H. A., and S. F. Cook. p. 243.*

Tissue slice water and electrolyte metabolism of adult cats during cold exposure. *Boatman, J. B.; P. A. Pisarcik, and M. J. Rabinovitz. p. 256.*

BRITISH MEDICAL JOURNAL. *Vol. 2, Aug. 1960.*

◇ **Cervical Disc Lesions with Neurological Disorder. A. M. G. Campbell, and D. G. Phillips. pp. 481-485.**

This work is a review of 60 cases treated by the authors for myelopathy or radiculitis associated with disorders of the cervical intervertebral discs and followed up for periods of two to ten years. The authors stress the point that in assessing prognosis and results of treatment it is essential to differentiate the various types of disorders associated with cervical intervertebral lesions. Main types of lesions may be classified under four headings: 1) cervical spondylosis with myelopathy; 2) cervical spondylosis with brachial neuritis; 3) prolapsed cervical nucleus pulposus, and 4) cervical spondylosis with myelopathy due partly or wholly to other etiology. Cases of brachial neuritis and of true disc prolapse with cord compression have a good prognosis- the first with conservative treatment, the second with surgery. Improved results in cases of cervical spondylosis with myelopathy have been associated with a conservative regime. A Minerva type of plaster collar has been used as the mainstay of conservative treatment in all but minor cases. The authors point out that conservative measures are often inadequately applied. Most reliance is placed on short plastic collars. While not generally used for cervical spondylosis with myelopathy, a Minerva type of collar, including the head and the upper chest, can hardly fail to give better immobilization of the whole cervical spine than shorter models. It prevents rotation or lateral flexion of the head, and allows movement of the lower jaw in eating and talking without movement of the occipito-atlantal or upper cervical joints. This is not so with a short collar fitting closely under the chin, when such movement is actually exaggerated. The authors advocate a better and larger use of the conservative treatment, which should be used reasonably early. Good results cannot be expected where symptoms have been present for over a year.

◇ **Effect of Physical Exercise on Alimentary Lipaemia. H. Cohen, and C. Goldberg. pp. 509-511.**

The authors studied the effect of exercise on the clearing of alimentary lipaemia, and the results of their observations are presented in this article. Twenty-two healthy students whose ages ranged from 20 to 25 years volunteered for the tests. The principle of the investigation was to measure plasma turbidity at a given time after a standard meal containing either 75 or 60 gm. of fat, with the subject resting; then to repeat the test under similar conditions except that the subject did a standard amount of physical exercise. Thus each individual acted as his own control. In a statistically significant number of cases the plasma turbidity was less after exercise than after resting. Since lipaemia is suggested to be the underlying cause of the intimal lipid deposition in human atherosclerosis, the authors' results might substantiate the observation that physical activity of work is a protection against coronary heart disease.

The Survey of Selected Literature for January 1961 was prepared by

Walter C. Stolov, M.D. *Seattle*	*for*	Journal of Physiology Neurology
Else A. Tophoj, M.D. *Odense, Denmark*	*for*	New England Journal of Medicine
Richard W. Stow, Ph.D. *Tehran, Iran*	*for*	American Journal of Medical Sciences American Journal of Physiology
John D. Guyton, M.D. *Worthington, Ohio*	*for*	Archives of Neurology
Osvaldo Miglietta, M.D. *Astoria, N. Y.*	*for*	British Medical Journal

book reviews

ANATOMY: A Regional Study of Human Structure. By *Ernest Gardner,* M.D.; *Donald J. Gray,* Ph.D., and *Ronan O'Rahilly,* M.Sc., M.D. Cloth. Price, $15.00. Pp. 999 with illustrations. W. B. Saunders Company, W. Washington Square, Philadelphia 5, 1960.

The reviewer is familiar with one previous work of the authors, Gardner's Neurology, and uses it frequently in classwork. This completely new human anatomy textbook has much to recommend it. It hits a nice balance between the necessities of a presentation by systems versus the desirability and unity of regional consideration while making no effort to be a surgical anatomy. The language is clear and concise. The dead thud of fact after fact which characterizes descriptive writing cannot altogether be avoided, but the authors handle it as well as any others I know. The elimination of eponyms except from the glossary at the end can be roundly cheered. Anatomy is difficult enough without a double, triple, and quadruple system of nomenclature. Some duplication in the nervous system is unfortunately necessary for the student to learn in order for him to translate current writing (e.g., middle cerebellar peduncle and brachium pontis). Our friends the surgeons are the chief offenders in perpetuating outmoded language like Poupart's ligament (which Poupart was not the first to describe). But the medical people offend also: auricle (diminutive of word meaning ear, referring to the appendage only) for atrium (meaning antechamber), the cavity proper. The text uses both terms.

The illustrations are very clear and are supplemented by some admirable photographs, including photographs of radiographs. All are in black and white. Perhaps we no longer need the traditional bichromes and polychromes in anatomy texts. After all they are not so in life nor in the cadaver.

I did not find any errors, although I was puzzled by the spelling of annulus fibrosus in description of the intervertebral disc (anulus means to me a diminutive of anus!). The print is very legible, with paragraphs set off in heavy type. Availability of bibliography at the foot of every page on which it is cited is a great convenience. The index appears adequate. The book does not adopt the embryological approach to understanding morphology, although developmental descriptions are inserted sufficiently to explain rotation and malrotation of the abdominal viscera and similar matters.

This book is not detailed enough to be a reference work in anatomy, although this is one of the three aims cited by the authors. For example it makes no mention of the joints of Luschka (those eponyms again!) in the cervical spine, although these joints are currently under scrutiny by clinicians as possible participants in certain pain syndromes of that region. It is also not organized in a manner to be an efficient dissection guide. The authors mention the well-known fact that the crowded medical school curriculum now has decreased time for anatomy. Certain it is that any medical student who thoroughly mastered the present work would have to be considered very well schooled indeed in anatomy. Perhaps the student's first text should be relatively simple and clear like this, and he should buy surgical atlases later if needed or more detailed reference type works for minutiae like the joints of Luschka.

This work is not my first choice but is among those recommended by me as a first text in anatomy. *(Sedgwick Mead, M.D.)*

OUTLINE OF ORTHOPAEDICS. By *John Crawford Adams,* M.D. Third edition. Cloth. Price, $8.00. Pp. 440, with illustrations. The Williams & Wilkins Co., Mt. Royal and Guilford Aves., Baltimore 2, 1960.

Excellent outlines of classifications of diseases and of routines of clinical examination of the different body parts are found in this volume directed toward students who are reviewing for examinations. The text itself is purposely devoid of detail, serving only as a reminder of main categories of diagnoses.

The author emphasizes the importance of adequate evaluation and has included concise outlines and well-thought out descriptions of examinations. There is profuse use of illustrations, both sketches and photographs, which compensates for the lack of detail in the text.

A chapter on non-operative treatment describes active and passive movements and electrical stimulation, but devotes more emphasis to manipulation. All sections concerning treatment are dogmatic and brief.

The style is crisp and the format excellent for stimulating quick recall. The volume can be highly recommended for the purpose of review of orthopaedic disabilities. *(Harriet E. Gillette, M.D.)*

ARTHRITIS AND YOU. By *James W. Brooke,* M.D. Cloth. Price, $3.00. Pp. 150. Harper and Brothers, 49 East 33rd St., New York 16, 1960.

Dr. Brooke has written this book for the patient with arthritis and for his family. It is well written, precise, scientific, and yet easily understood. It has a definite value as an adjunct to medical treatment.

Dr. Brooke attempts to cover the general subject of arthritis, explaining by chapters what it is, what the general fate of the arthritic might be, the suspected causes, the current ideas concerning the cause, the time-honored remedies both good and bad, the present programs of treatment, surgery, the current directions of research and, finally, what should the arthritic patient do. In discussing the present programs of treatment, rest is emphasized. Physical therapy is discussed with the idea that heat and massage in itself is of little value if a proper program of mobilization is not supplied as well. There must be reduction in deformity and general proper attention to posture. The fact that physical therapy is of value in the acute stages as well as throughout the disease is definitely emphasized. The limited but often valuable use of x-ray therapy, particularly in ankylosing spondylitis, is discussed. Under medicines: salicylates, gold, phenylbutazone, the steroids, colchicine and benemid, the antimalarial drugs, as well as such agents as muscle relaxants, thyroid, iron, vitamins, intravenous cocaine, sex hormones and the various vaccines. The approach is practical and sensible throughout.

Under "What should the arthritic patient do" the selection of a physician is discussed, explaining that certain people are particularly interested in arthritis while others are not, that the Rheumatism Foundation or the American Rheumatism Association might be of assistance.

Dr. Brooke is connected with the Eugene Clinic, Eugene, Oregon. He is particularly interested in the arthritic diseases. He has specialized in Sweden and England as well as in the United States. The book is one that can be read by the patient and by many individuals with moderate interest in arthritis, both medical and paramedical. *(Frances Baker, M.D.)*

EXERCISE AND FITNESS: A Collection of Papers Presented at the Colloquim on Exercise and Fitness, sponsored by the University of Illinois, College of Physical Education and the Athletic Institute. Paper. Pp. 248, with illustrations. Price $3.00. The Athletic Institute, Chicago, 1960.

Twenty-one papers, all by outstanding authorities with various backgrounds; physiologist, physical education, physicians, nutritionists, psychologists—many of which present specific scientific data and others discuss the findings of various researchers in relation to the subject which they are discussing. The overall purpose of the colloquim was to review the effects of exercise on fitness with a focus on human beings and hygiene. Exercise was interpreted to be any type of physical activity; fitness referred to the organic condition of the body; motor ability to strength, endurance, mobility, etc.

A mass of very important scientific data and research facts has been collected in these papers and, as is true in research, there are controversial points where other research failed to confirm or duplicate previous work, or else there is still not sufficient research data available to arrive at a final decision. Most significant and vitally important are the very significant points of agreement: that every individual must have adequate and sufficient active physical exercise throughout his life, if the organism is ever to function at maximum efficiency. Of the greatest significance is this statement in Chapter 21, Summary and Comments, "Today we are convinced of a high correlation between inactivity and diseases of the circulatory system: but we are also ready to declare that there is not enough evidence to say that inactivity is a cause of such disease. Although we cannot honestly claim that exercise reduces the incidence of heart disease, we can say that exercise does not bring on heart disease and we have been reminded that a period of strenuous training generally increases the tonic effect of the vagus on the heart, and probably also, inhibits the sympathetic tone." Enough data was presented to appear to exonerate high blood cholesterol as the cause of blood vessel disease, but rather to consider its evaluation as a metabolic sign only in a symptom complex, connected with lipid metabolism, but where improper diet or exercise and emotion are in some way related to atherosclerosis.

Interesting points regarding nutrition were discussed, of which the report that there seems to be a fundamental difference in the intermediary fat metabolism of fats in those who are thin and those who are fat, deserve special attention. Various faddist diets, as well as training table routines came under scrutiny. This same discussant pointed out the fallacy of continuing to think that exercise stimulates appetite and thus increases weight, whereas driving a 2½ mile trip to work daily will put on one pound in 13 days. Physical education for all pupils in every school grade was recommended to offset the caloric economies of school buses and T.V. sets. Furthermore, exercise programs for adults are ineffective with only occasional week-end exercise programs, especially as regards the mounting obesity in our population. Fitness can and should be measured, but it also must be evaluated, for it has many facets and various values to society. Personality structure and changes in personality traits is another phase of the overall. The goals of persistent and strenuous exercise are many and their importance, if only in terms of the improvement

of the organic structure, and assistance in health maintenance, was repeatedly mentioned.

Some old empyrical statements were destroyed; others could not be confirmed by other researchers; new data was presented, much with research statistics. Factors of tests and measurement were gone into with detail. No doubt is left but that everyone of every age must have exercise, if the efficiency of the organism is to be maintained. Most significant is the relation of lack of exercise to the prevalence of atherosclerosis (and specifically to coronary disease) and the additional but related problem, of increasing obesity of our population of all ages, as is related to disease of the circulatory system. These facts alone, make this collection of papers most important reading for every physician and any others who are concerned with the continued high death rate from heart disease, but who are also concerned in looking for and finding, solutions to these problems. *(Nila Kirkpatrick Covalt, M.D.)*

ELETTROMIOGRAFIA CLINICA. By *Carlo Serra* and *Lucio Covello*. Italian monograph. Cloth. Price, not given. Pp. 507, with illustrations. Acta Neurologica, Napoli, Italy, 1959.

This book is the result of a truly enormous amount of work. The authors begin with a review of currently understood physiology of the spinal synapse, of the motor end plate, and of the molecular anatomy and spread of excitation within a single muscle fiber. Effects of drugs and thermal agents and ischemia are next considered. The clinical section then covers the neuritides and myopathies usually surveyed in works on electromyography, adding a number of chapters of observations on internal medicine, ophthalmology, laryngology, etc. The work concludes with a very large bibliography and index.

One can but admire the thoroughness with which this work has been carried out. I have not seen elsewhere the technic of multipolar recording from a single needle electrode (the sheath fenestrated at ten or more points along its shaft). Study of the form of a single potential simultaneously recorded at measured distances from its exact origin is certainly rewarding.

The authors have placed emphasis on the clinical value of electromyographic studies of this type and with this point of view I must mildly disagree. What the busy clinician seems to want and was disappointed in getting in, for example, ballistocardiography and vectorcardiography, was some kind of magic touchstone which would pop out a neatly printed card with the words "Anteroseptal infarct of 11 days' duration, superimposed on posterior wall ischemia of ancient date."

Well of course electromyography is not going to provide information like this. It is singly diagnostic of almost nothing. An EMG record couldn't be sent to an expert on vacation and the diagnosis come back in the next mail. But to a physiologically minded, thoughtful man it certainly is a valuable if dispensable adjunct to all the normal methods of investigation.

This book is highly recommended as a definitive reference work on electromyography. *(Sedgwick Mead, M.D.)*

ARTHRITIS AND ALLIED CONDITIONS: A Textbook of Rheumatology. Edited by *Joseph Lee Hollander*, M.D. Cloth. Price, $20.00. Pp. 1306, with illustrations. Lea & Febiger, Washington Sq., Philadelphia 6, 1960.

This book represents a complete text on the arthritic diseases and associated diseases. Eight section editors assist Dr. Hollander and are in turn assisted by thirty contributing editors who write chapters to make up the various sections. The authors are well known to all who are interested in arthritis. They are most active members of the American Rheumatism Association. They are clinicians actively interested in research and in teaching.

The subject of the rheumatic diseases as a whole is well covered and over five hundred pages is allotted to rheumatoid arthritis alone. Another section is devoted to rheumatic diseases resembling rheumatoid arthritis and includes spondylitis, psoriatic arthritis, rheumatic fever, palindromic rheumatism, intermittent hydrorthrosis, and the fibrositis syndrome. Sections are allotted to the connective tissue diseases, to degenerative joint disease, to metabolic bone and joint diseases, to specific infections causing arthritis, to certain conditions complicating or producing arthritis such as amyloidosis, sarcoidosis, disorders of hemopoiesis and blood coagulation, neuropathic joint disease, developmental connective tissue disorders, and tumors of joints and tendon sheaths. In another section, headed "Regional Disorders of Joints and Related Structures," traumatic arthritis, internal derangement of the knee joint, painful feet, the syndrome of cervical nerve root compression, the painful shoulder, Dupuytren's contracture, and low back pain with sciatica are discussed.

The chapters of each section are well illustrated. It is interesting that the outline of the chapter is boxed in to clarify the subject and bring it before the eye quickly. Each chapter, of course, has its own good bibliography.

The chapters on physical therapy and occupational therapy are written by Morris A. Bowie of the University of Pennsylvania. To me, these chapters are most disappointing. Every source of heat is described, many of which have been discarded. The programs of exercise are of the type that could be written by any corrective therapist. No attempt has been made to describe ways by which deformities can be overcome or function can be

augmented to prevent or overcome deformity to develop correct rhythms of movement as concepts of functional anatomy would indicate.

This is a most outstanding book. Any physician with the slightest interest in rheumatology should possess this book for constant reference. It should be a most valuable textbook and reference in every school of medicine. It cannot be too highly recommended. *(Frances Baker, M.D.)*

CLINICAL ORTHOPAEDICS. No. 15: The Hand, Part 2. Edited by *Anthony F. DePalma,* M.D. Cloth. Price, $7.50. Pp. 211, with illustrations. J. B. Lippincott Co., E. Washington Sq., Philadelphia 5, 1959.

This volume is No. 15 in a series which has become a classic in orthopaedic literature. Many of the articles have been written by outstanding orthopaedic surgeons who have since gained recognition in the areas they have covered in this text.

The articles are easily readable and well illustrated with excellent photographs and drawings. This particular volume is concerned primarily with the subject of surgery of the hand, specifically plastic repair. The material, therefore, is likely to be of background interest for the physiatrist rather than an area of primary concern. *(Jerome S. Tobis, M.D.)*

BACKGROUND PAPER ON RESEARCH IN GERONTOLOGY: MEDICAL. White House Conference on Aging. Prepared under direction of the Committee on Research in Gerontology: Medical. White House Conference on Aging, Jan. 9-12, 1961. Paper. Price, not given. Pp. 139. Ewald W. Busse, M.D., Chairman, Medical Research Committee on White House Conference on Aging.

Much effort has been expended in preparation for the White House Conference on Aging to be held in Washington, D. C. during January 1961. There are 20 subject matter areas, one of which is Research in Gerontology: Medical. This pamphlet has been prepared by experts associated with the Medical Research Committee. It deals with medical disorders which may affect our older citizens. The purpose of the pamphlet is to prepare those who have any interest in this area to ready themselves for the Conference and to communicate their ideas to others who are concerned. This will permit a broad base of intelligent preparation to present an agenda of adequate depth to guide the meetings and plan the future beyond the Conference in this particular aspect of aging.

The authors make clear that the scope of this paper may be altered as a result of suggestions and that sections may also be changed if necessary. The paper contains a wealth of well-selected material that will serve to establish the beginning of a firm foundation for preparation for one Conference area.

When we consider this paper as one of numerous meticulous efforts in preparation, we may honestly express a hope that something wonderful will come from the White House Conference on Aging. *(Charles D. Shields, M.D.)*

BONE TUMORS, Second edition. By *Louis Litchtenstein,* M.D. Cloth. Price, $12.00. Pp. 402, with 220 illustrations. C. V. Mosby Company, St. Louis, 1959.

The non-committal title of this well-known book, now being published in its second edition, is aptly chosen, since it avoids reference to any given field. It is not an extended treatise on the pathology of bone tumors specifically, nor on the surgical management of them, nor on the radiologic recognition and, occasionally, treatment of them; yet it is all of these without undue emphasis on any given one. Thus, the purpose of the lack of qualification of the title becomes apparent. It is designed to be a guide to the broader recognition, treatment, and management of bone tumors and of lesions simulating them. That it has come to a second edition testifies to the enthusiastic reception of the book in its first edition and to the advances in knowledge of all aspects of bone tumors since the publication of that edition.

As the author points out in his preface to the second edition, the amendments include the addition to the book of new illustrations and of chapters on tumors of periosteal origin, synovia, bursae, and tendon sheaths, as well as on non-neoplastic lesions which may be mistaken for tumors. Not specifically mentioned are the considerably enlarged bibliography, which has been brought up to date, and the expanded experience of the author and others in the field of bone pathology, many of whose findings have been included in the text. While there is no self-effacing underevaluation of the present state of knowledge and of past achievements, the areas yet to be confronted are faced honestly, and the possibility of continued obscurity or complete ignorance in some of these areas is fully recognized.

The second edition continues the high level established in the first edition, and although, quite justifiably, the orientation remains basically pathological, this merely emphasizes the essential role of pathologic precision in the larger area of clinical management and does not represent an argument for arid academism or a defense of pathologic esoterica. To this end, the brief chapter on the clinical management of possible bone tumors, addressed to pathologists as well as to surgeons and roentgenologists, has been added.

From a purely pedagogic point of view, the book incorporates numerous desirable features. There is a regularly recurring mode of exposition within clearly-defined units: Introduction, Clinical Features, Pathology, Treatment and Prognosis, Summary, and References.

The figures are well reproduced, and full justice has been given to the roentgenographs. There are few typographical errors, and those which are glaring are generally not misleading. A single exception might be the statement in the middle of page 73, which describes a tumor ". . . found in the mataphysical area . . ." — rather a shock to those among scientists whose philosophic leanings are in the direction of logical positivism (!).

The book can be highly recommended to those whose needs are slightly less than special: to the pathologist who needs to know more about the clinical management of bone tumors, to the surgeon who needs to know something of the histologic and roentgenologic features of tumors, to the clinician who simply needs to know something about tumors of bone from the vantage point of a larger perspective. It is the inclusiveness and sense of proportion, as contrasted with intensive, monographic discussions of special aspects, which constitute the strongest recommendation for the book as a whole. Its authoritativeness stands unquestioned. *(Thomas P. Anderson, M.D.)*

PHYSICS AND ELECTRONICS IN PHYSICAL MEDICINE. By *A. Nightingale*, M.A., Ph.D. Cloth. Price, $6.00. Pp. 292, with 320 illustrations. The MacMillan Company, 60 Fifth Ave., New York 11, 1960.

This book fills a definite need. While some of the textbooks on Physical Medicine contain chapters on the physical basis of the subject, they are usually short and consequently insufficient. On the other hand, to cull the physical principles underlying Physical Medicine from standard physics textbooks is a difficult task. The present book gives a rather elementary yet accurate account underlying the many physical methods of diagnosis and treatment employed in Physical Medicine. The text is well organized and illustrated by an abundance of simple but instructive line drawings. The first part of the book deals with fundamental principles of physics, such as structure of matter, mechanics, heat, wave motion, electric currents and electric circuits. This is followed by a second part, describing the more common applications of these physical principles in Physical Medicine. In the last part, an appendix, more difficult topics such as the cathode ray oscilloscope, electromyography, "constant-current" and "constant voltage" stimulators, microwave diathermy, ultrasonic therapy and transistors are discussed. This part also contains a section on "some useful mathematical techniques." The book can be highly recommended to medical students, specialists in Physical Medicine, neurologists and physical therapists. *(Otto Glasser, Ph.D.)*

ANNUAL REVIEW OF MEDICINE, VOL. 11. Edited by *David A. Rytand*. Cloth. Price, $7.00. Pp. 453. Annual Reviews, Inc., Palo Alto, California, 1960.

It is a pleasure to review again this growing series. No attempt is made to cover the whole field of medicine in any one year. The group of reviewers who are busy summarizing this year will publish next year, and so on.

Not only is the whole field of medicine not covered; only selected phases of any particular subject are covered. This selectivity would appear to impair the usefulness of these volumes as reference material. But they are valuable reference material if one retains the whole series. The subjects are of course not adequately covered — any of them — for a specialist working in a particular field. Rather they give a working summary of up-to-date knowledge of decided help to the practitioner.

I selected for reading the chapters on Infectious Disease, Bacterial; Arterial Hypertension; Hormonal Control of Pigmentation; The L. E. Cell Phenomenon; Neoplastic Disease; Behavioral Problems of Adolescents; and Congenital Enzyme Defects.

This volume is highly recommended as a reference work. The bibliographies will lead the enquirer to further relevant literature. *(Sedgwick Mead, M.D.)*

FUNCTIONAL ANATOMY OF THE LIMBS AND BACK. By *W. Henry Hollinshead*, Ph.D. A text for Students of Physical Therapy and Others Interested in the Locomotor Apparatus. Cloth. Price, $9.00. Pp. 403, with illustrations. Second edition. W. B. Saunders Co., W. Washington Square, Philadelphia, 1960.

I first reviewed this text when its first edition came out and found it at that time a very useful text indeed, especially for students of physical and occupational therapy and for nurses and other paramedical personnel as well. There are new additions in this volume, particularly concerning the nervous system. The illustrations, mainly line drawings, emphasizing salient points, are clear and very pleasing. It is difficult to write interestingly about anatomy, but the author succeeds uncommonly well. He devotes a good deal of thought to the kinesiology of the musculoskeletal system, as would be expected from the title.

This book should be welcomed by teachers of physical therapy and allied arts. It is far from formidable for the student and recommended by the reviewer. *(Sedgwick Mead, M.D.)*

FRACTURES & ORTHOPAEDIC SURGERY FOR NURSES AND PHYSIOTHERAPISTS. By *Arthur Naylor,* Ch.M., M.B. Cloth. Price, $6.50. Pp. 358, with illustrations. The Williams & Wilkins Co., Mt. Royal and Guilford Aves., Baltimore 2, 1960.

This handbook is prepared for the use of those who assist the orthopedic surgeon in his practice.

The author defines rehabilitation as "the mechanism of placing the patient in a position to pursue his former or equivalent occupation by means of surgery, nursing, physical and psychological treatment and requires cooperation between surgeon, nurse, masseuse, patient and employer." The term physiotherapy is used throughout the book and on page 83 passive physiotherapy is defined as meaning massage, heat and electrotherapy. In my opinion these definitions reflect a concept of medical rehabilitation and physical therapy that is somewhat different from our ideas in the United States of America.

There are chapters devoted to apparatus and to operating room technics. The discussion of bracing and functional devices emphasizes immobilization. There is broad, general discussion of many orthopedic conditions.

The book contains excellent photographs and diagrams and is well indexed. It is well suited to the orthopedic office assistant and will prove of value to the nurse working with orthopedic patients. *(Charles D. Shields, M.D.)*

A PSYCHIATRIST'S WORLD: The Selected Papers of *Karl Menninger,* M.D. Edited by *Bernard H. Hall,* M.D. Cloth. Price, $10.00. Pp. 931. The Viking Press, Inc., 625 Madison Avenue, New York 22, 1959.

"A Psychiatrist's World" is the world of Karl Menninger, as seen through his selected papers. The choice of papers was no easy task, for in the last forty years, this prolific writer has published over two hundred articles (listed separately), in addition to a number of books which introduced psychiatry to the general public in a palatable form. Karl Menninger is probably the best known living psychiatrist today. The editor, Dr. Bernard Hall, describes him aptly: "Karl Menninger happens to be a psychiatrist. He is also a physician, a psychoanalyst, a teacher, a writer, an administrator, a theorist, and a researcher. . . . He is a lot of other things, too." Thus the papers are not arranged chronologically but in six parts: The Man, The Clinician, The Theorist, The Teacher, The Psychiatrist Afield and the Historian of Psychiatry. Each section is skillfully introduced by the editor.

Not only did Karl Menninger contribute significantly to psychiatry, he made psychiatric history. He and his brother William founded the Menninger Clinic in Topeka, a mecca of world psychiatry. The evolution of psychiatric development in this country becomes obvious when we compare the author's earlier works with his more recent writings. It is interesting to read Karl's own analysis of his previous concepts of disease: "I am somewhat ashamed to admit that it has taken me a quarter of a century to realize that this formula (treating the patient according to his diagnosis) rarely works out this way in actual practice . . ." Dr. Menninger was among the pioneer proponents of the holistic or total personality principle.

Although the book is over nine hundred pages long, every chapter is stimulating and challenging. However, the selection of papers has been somewhat of a disappointment to this reviewer. Karl Menninger is one of the small number of psychiatrists (and particularly psychoanalysts) who have shown more than casual interest in physical medicine. He has written about the contribution of physical medicine to the management and rehabilitation of the mentally ill and has also interpreted the psychological aspects of physical and occupational therapies. It is regretable, therefore, that very few of these discussions are included in this volume. There is, however, an interesting article "The Abuse of Rest in Psychiatry," a critique of Weir Mitchell's "rest cure."

The book offers a liberal education not only in psychiatry but also in many other related fields. *(Jack Meislin, M.D.)*

ANNUAL REVIEW OF PHYSIOLOGY. Vol. 22. Edited by *Victor E. Hall.* Cloth. Price, $7.00. Pp. 726. Annual Reviews, Inc., Palo Alto, Calif., 1960.

Intelligent reading of all chapters of the Annual Reviews is becoming with the years a more difficult task for the reviewer. The reader is able to absorb the material from those chapters of his major interest; the chapters dealing with subjects of his casual interest are often like midchapters in a serial story, the early chapters of which are only hazily recalled. Of course, the various chapter authors vary in their ability to compose a well-rounded review article. The volume of current literature is so great that there is scarcely space for the author to tie the chapter together into a unit.

Regardless of the detailed material content, this volume furnishes a revealing commentary on current trends of interest and accomplishment. The great strides being made in nuclear physiology and chemistry are clearly evident. Throughout there is an increased merging of physiology and chemistry. The wealth of material on the nervous system requires the division of the material into four chapters:

the divisions of the subject are somewhat arbitrary and overlapping, but probably as good as is possible. The chapters on comparative physiology of muscle metabolism and blood pigments were particularly useful in expanding this reader's concepts of these subjects. *(R. C. D., M.D.)*

THE UTRECHT SYMPOSIUM ON THE INNERVATION OF MUSCLE. Edited by *H. D. Bouman,* M.D., and *A. L. Woolf,* M.D. Cloth. Price, $5.00. Pp. 223, with illustrations. The Williams & Wilkins Co., Mt. Royal & Guilford Aves., Baltimore 2, 1960.

All of the papers in this publication originally appeared in 1959 and 1960 in volumes 38 and 39 of the *American Journal of Physical Medicine.* The editors and publishers have reissued the papers in this symposium in a single volume as a permanent record of the Utrecht Symposium on The Innervation of Muscle, which was held in July, 1957. This book will be of use primarily as a reference work for neurologists, pathologists, neurophysiologists, and physiatrists particularly interested in basic research on the physiologic aspects of innervation of muscles. The contributions come primarily from European physiologists, pathologists, and neurophysiologists. Several clinicians are represented among those who presented papers for this symposium. A few of the contributors' names familiar to clinicians in physical medicine and rehabilitation are: Philippe Bauwens, A. T. Richardson, E. Gutman, and F. Buchtal.

Many aspects of the physiology of muscle and nerve and studies of the transmission of the nerve impulse are presented. Features of electrodiagnosis, electromyography, neuromuscular physiopathology, and chemical studies of conduction mechanisms are included in the subject matter covered in this symposium. A long and interesting chapter by J. D. Robertson is devoted to electron microscopy of the motor end-plate and the neuromuscular spindle. Several clinical conditions are discussed, including denervation, myasthenia gravis, reinnervated muscle and hemifacial spasm, and muscular myotonias of infancy.

Most of the subject matter is presented in a readable manner, although some of the research articles are a bit overwhelming for the ordinary clinician. The subjects are well arranged, and the illustrations and diagrams, which are in black and white, are legible and clear. Each chapter contains a useful bibliography for those who desire further reading and study.

This book should be available in medical schools and wherever research is carried on relative to the neuromuscular systems. It would be of limited value to the ordinary clinician in physical medicine and rehabilitation. *(Gordon M. Martin, M.D.)*

READINGS IN REHABILITATION COUNSELING. Edited by *C. H. Patterson.* Paper. Price, $5.25. Pp. 324. Stipes Publishing Co., 10-12 Chester St., Champaign, Ill., 1960.

C. H. Patterson, Associate Professor of Education and Director of Rehabilitation Counselor Training, University of Illinois, Urbana, has edited a compilation of articles by 63 authors concerning various aspects of rehabilitation counseling. Most of the papers were published previously. The editor indicates that he has attempted to gather relatively recent articles which present significant concepts of interest to students and counselors in the field of rehabilitation.

The articles are arranged in 10 different sections, each of which has been introduced by the editor. Some background information on the history and philosophy of rehabilitation is given. However, the practical emphasis throughout the book is on the various concepts of and technics for vocational counseling, training, and placement. Problems related to all aspects of rehabilitation are faced quite realistically in most of the articles. The articles selected do not include many statistical data or much information about research studies, since, as the editor states, this material is intended primarily as background reading for persons in rehabilitation counseling.

The type is somewhat small for easy reading, and there are no illustrations. A few of the articles have a limited bibliography. The style of writing, of course, varies with the author. For the most part, however, the articles are quite readable. As indicated, this collection of articles will be of value primarily to students and workers in vocational rehabilitation and rehabilitation counseling. The physician will undoubtedly be aware of the lack of emphasis on the essential role of the physician in the over-all rehabilitation program. The book may be of some aid to physicians in physical medicine and rehabilitation in acquainting them with the concepts of some of the other workers in this developing field. *(Gordon M. Martin, M.D.)*

A PRIMER OF ELECTROCARDIOGRAPHY. By *George E. Burch,* M.D., and *Travis Winsor,* M.D. Cloth. Price, $5.00. Pp. 293, with illustrations. Lea & Febiger, Washington Sq., Philadelphia 6, 1960.

The authors state that the word primer is in fact the purpose of this book. It is not intended as an encyclopedia, a scientific treatise or a review of the current literature of electrocardiography. The approach is that of acquainting the medical student, intern and resident with the physiologic and electrical principles of the electrocardiogram.

To the extent that is above mentioned, to fulfill this objective, the authors have worked diligently to present the simple facts as they

are taught today about the physiology of the wave(s) of conduction through the heart. This they reduce to the simplest recording methods and explain how the conduction wave produces the electrocardiogram. They point out the difference in appearance with the different lead-off electrodes. The most frequently occurring abnormalities are explained and illustrated in the same manner.

The presentation is clear and easily understood. The format is acceptable. Two minor criticisms might be mentioned: 1. There is a complete repetition in the text and in the description of each illustration. Perhaps for the student who studies the illustration and less so the text, this is a necessary objective; and 2. Some of the illustrations precede and some follow the text. This makes it difficult to follow the text and refer to the illustration simultaneously. However, with so many illustrations and in many instances such a short narrative, this is unavoidable. Since visual education is more lasting, the illustrations are necessary.

This book does essentially what the authors intended and its fourth edition is evidence thereof. The reviewer is reminded of Dr. Richard Ashman's lectures in physiology and of his textbook "Essentials of Electrocardiography" more than twenty years ago. The complete absence of any bibliography is probably unfortunate, for any ambitious student of electrocardiography should be given leads to other workers and their work. The book is handy to have as a ready reference to the basic principles of electrocardiography.

ESSENTIALS OF ORTHOPAEDICS. By *Philip Wiles,* F.R.C.S. Third edition. Cloth. Price, $13.00. Pp. 576, with 417 text figures. Little, Brown and Company, 34 Beacon St., Boston 6, 1959.

This is a basic textbook on orthopedics, by an outstanding British authority. Having set as his objective the delineation of the physiologic and pathologic ramifications of musculoskeletal disease and injury, the author methodically executes his plan. The result: a well-rounded textbook that covers most of the problems usually associated with this specialty.

The format is rather unusual and requires a few words of comment. Instead of dividing his book into general categories as most authors do, Dr. Wiles, after an initial chapter devoted to postural defects, and a second chapter on back pain, then devotes seven chapters (III through IX) to the various joints and their particular problems. This results necessarily in a certain amount of repetitiousness, since the joints are predisposed to similar diseases. On the other hand, this very repetitiousness promotes a better understanding of the problems peculiar to each disease as it applies to the individual joint. The second half of the book adheres to the more classic format. Chapter X deals with Pyogenic Infection, Chapter XI discusses Tuberculosis of joints and bones. Chapter XII is devoted to Chronic Arthritis, including rheumatoid arthritis, osteoarthritis, and neuropathic arthritis. Chapter XIII deals with benign and malignant tumors of bones, primary and metastatic. Chapter XIV discusses Blood and Allied Diseases affecting bone. Chapter XV is a discussion of metabolism and other disorders affecting bone. Chapter XVI has to do with congenital defects of the skeleton. And the last chapter (XVII) deals with Diseases of the Nervous System, as they pertain to orthopedics.

The subjects discussed are well-covered from the standpoint of physiology and pathology. Orthopedic management is given adequate coverage for the most part. But physical therapy could have received a little greater attention. The book is carefully written and proofread, although an occasional error has crept in, such as including the carpal tunnel syndrome in the chapter on the shoulder girdle, and leaving out the word "not" on page 47 — "No greater force is necessary when an anesthetic is (not) used."

The type is highly legible. "Dodge" printing is used to reproduce the high contrast radiographs, which are unusually clear. The style is easy. The bibliography at the end of the book is very helpful. The index is adequate.

The book is recommended to students, general practitioners, orthopedic residents and surgeons, and to physiatric residents and specialists, as well as to physical and occupational therapists. *(Harry T. Zankel, M.D.)*

ARTHRITIS: General Principles Physical Medicine Rehabilitation. Edited by *Edward W. Lowman,* M.D. Cloth. Price, $9.50. Pp. 292, with illustrations. Little, Brown and Company, 34 Beacon St., Boston, 1959.

In this volume of 24 chapters written by outstanding authorities from various fields, Doctor Lowman has assembled information on all facets of management of rheumatoid arthritis.

The tone of the book is eminently practical without sacrifice of scientific accuracy. The chapters on physiology and pathology can be understood by non-medical readers, and are profusely illustrated with photographs and diagrams.

The chief worth of the volume, valuable in its entirety, lies in the chapters on Physical Medicine and Rehabilitation Treatment, where is summarized the basic programs of exercise, transfer and self-care technics, and assistive devices. The astute reader will apply these principles to a wider field than that of arthritis.

The format is excellent; style in most of the chapters is clear, direct, and lacking in superfluities. The wide use of meaningful illustration is to be commended. The book should be included as basic material in every library. *(Harriet E. Gillette, M.D.)*

REHABILITATION OF THE MENTALLY ILL. Edited by *Milton Greenblatt* and *Benjamin Simon*. Cloth. Price, $5.00. Pp. 260, with 3 illustrations. American Association for the Advancement of Science, 1515 Massachusetts Ave., N.W., Washington 5, 1959.

Rehabilitation of the mentally ill is one of the most cogent problems faced by our society not only as a medical challenge but also because of its social and economic implications. In a way, psychiatric rehabilitation — preparation for optimum adjustment in the community — is more of a "total rehabilitation" problem than that of the physically disabled: it is often a reeducation in life from a state of childhood to which many of our mental patients regressed in their course of illness. There are no prosthetic appliances such as we have for the physically handicapped to substitute for the disturbed function of the mind. Recently American psychiatry got a jolt similar to that dealt to our technical sciences by the Russian sputnik. We are beginning to realize that, with all our economic resources, we are quite behind our European colleagues in many aspects of our approach to the problems of the mentally ill. Many of these problems are discussed in this book and, although no panacea is offered, the publication can be of great practical value to all interested in mental health.

The book is the outcome of a symposium on rehabilitation of the mentally ill edited by Milton Greenblatt, Director of Research of the Massachusetts Mental Health Center (Boston Psychopathic Hospital) and Benjamin Simon, Chairman of Committee on Rehabilitation of the American Psychiatric Association. It was my privilege to work with Dr. Simon on that committee. The symposium is divided into several parts: General Problems, Hospital Aspects of Rehabilitation, Transition from Hospital to the Community and Community Aspects of Rehabilitation.

Members of the various panels discuss problems, solutions and offer critiques of our present management of psychiatric patients. For instance, there is a challenge of our criteria for hospitalization of these patients. Some believe that mental illness *per se* is not a reason for hospitalization but rather consideration of safety or special treatment not feasible on an outpatient basis. What is activity therapy and how should it be administered? What is the role of "attitudes" of rehabilitation therapists? What is the present contribution of occupational therapy in the process of rehabilitation? Are we on sound ground in believing that the ex-hospital patient should sever all ties with his "alma mater"? How intensive should our hospital vocational programs be?

Various methods of rehabilitation, including Industrial Therapy, Day and Night and Member-Employee Programs, Half-Way Houses and Sheltered Workshops are described.

The book is a must for all workers in the field of rehabilitation of the mentally ill. *(Jack Meislin, M.D.)*

SURGICAL PATHOLOGY. By *Lauren V. Ackerman*, M.D., and *Harvey R. Butcher, Jr.*, M.D. Cloth. Price, $15.00. Pp. 1096, with illustrations. C. V. Mosby Company, 3207 Washington Blvd., St. Louis 3, 1959.

This book is an encyclopedia of detailed introduction in the field of surgical pathology — it is not a textbook of general pathology. The text does not run the gamut of surgical lesions since the emphasis has deliberately been placed on the common lesion. Recent advances in surgery, including anesthesia, antibiotics, resuscitation and supportive technics, permits the modern surgeon to perform procedures once considered "tour de force" or actually impossible, thereby permanently altering the patient's physiology and all this fact implies for him. Surgical pathological lesions are, therefore, of paramount interest to the modern surgeon and this book describes them in detail.

The book has been written for the student, as well as the physician who is daily concerned with the lesions described. Thus, it has been organized along organistic, regional and body system lines. The chapter on "Skin" has a special section on wound healing which is timely and well written. The chapters on "Oral Cavity" and "Mandible and Maxilla" taken together, include a majority of the lesions of the face, except for the salivary glands. The major number of the chapters, however, deal with body organs or systems.

Several special sections of the book have been individually rewritten or revised by the original authors except the section on non-neoplastic conditions of the skin, originally written by the late Dr. Zola K. Cooper and revised by Dr. Robert Ogilvie.

This second edition has been entirely revised and updated. It also represents the rare occasion when a pathologist and a surgeon have collaborated on such a book, and as such it should have special appeal to both specialty groups. It is well written in an easily readable style and the quality of the book itself is first-class in all respects. *(J. H. K.)*

FRACTURES, DISLOCATIONS AND SPRAINS. By *Philip Wiles*, F.R.C.S. Cloth. Price, $7.50. Pp. 67, with 519 illustrations. Little, Brown and Company, 34 Beacon St., Boston, 1960.

The book was produced to furnish a "short, generously illustrated volume supplying in succinct form the information necessary for the diagnosis and treatment of fractures and dislocations." Each complete story is contained on two pages with x-rays, drawings and the explanation of mechanism for the injury, the diagnosis, treatment and complications.

The author originally had large hand-lettered cards with drawings and x-rays which were used for teaching and review in the hospital. They cover the subject very well. The author has not delved into controversy in the matter of treatment but has given only his own conservative method of handling each type of injury. This should not be misconstrued to mean that this is the only method of handling an individual case. There is no bibliography. His own international recognition vouches for the reliability of the contents of the book.

Operative procedures are mentioned but not described. Illustrations are well and simply drawn to explain the x-ray findings which are found on the facing page in each instance. There is no flipping of pages to follow the context of the written word and the illustrations or x-rays. Being set up in this format makes the book easy to study. It is a book to be highly recommended for anyone who must care for patients with orthopedic conditions.

Of the many things man can do or make here below, by far the most momentous, wonderful and worthy are the things called Books.

— THOMAS CARLYLE

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Announcing . . .

The Eighth Essay Award

sponsored by the

AMERICAN CONGRESS OF PHYSICAL MEDICINE AND REHABILITATION

To stimulate interest in the field of physical medicine and rehabilitation, the American Congress of Physical Medicine and Rehabilitation will award annually, a prize for an essay on any subject relating to physical medicine and rehabilitation. The contest, while open to anyone, is primarily directed to interns, residents, graduate students in the pre-clinical sciences and graduate students in physical medicine and rehabilitation. The Awards and Prizes Committee suggests that members of the American Congress and American Academy of Physical Medicine and Rehabilitation bring this announcement to the attention of interested persons. The following rules and regulations apply to the contest:

1. Any subject of interest or pertaining to the field of physical medicine and rehabilitation may be submitted.

2. Manuscripts **must be** in the office of the American Congress of Physical Medicine and Rehabilitation, 30 N. Michigan Ave., Chicago 2, not later than March 1, 1961.

3. Contributions will be accepted from interns, residents, graduate students in the pre-clinical sciences, and graduate students in physical medicine and rehabilitation.

4. The essay must not have been published previously.

5. The American Congress of Physical Medicine and Rehabilitation shall have the exclusive right to publish the winning essay in its official journal, the ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION.

6. Manuscripts must not exceed 3000 words (exclusive of headings, references, legends for cuts, tables, etc.), and the number of words should be stated on the title page. An original and one carbon copy of the manuscript must be submitted.

7. The winner shall receive a cash award of $200.

8. The winner shall be determined by the Awards and Prizes Committee of the American Congress of Physical Medicine and Rehabilitation.

9. All manuscripts will be returned as soon as possible after the name of the winner is announced.

10. The American Congress of Physical Medicine and Rehabilitation reserves the right to make no award if, in the judgment of the Awards and Prizes Committee, no contribution is acceptable. Announcement of the winner will be made at the annual meeting.

BERNARD M. BARUCH ESSAY AWARD—*iv*

Sponsored by the

AMERICAN CONGRESS of PHYSICAL MEDICINE AND REHABILITATION

An annual award of $100 will be given as a prize for an essay on any subject relating to physical medicine and rehabilitation.

The following rules and regulations apply:

1. Any subject of interest or pertaining to the field of physical medicine and rehabilitation may be submitted.

2. Manuscripts **must be** in the office of the American Congress of Physical Medicine and Rehabilitation, 30 N. Michigan Ave., Chicago 2, not later than March 1, 1961.

3. *Contributions will be accepted from medical students only.*

4. The American Congress of Physical Medicine and Rehabilitation shall have the exclusive right to publish the winning essay in its official journal, the *Archives of Physical Medicine and Rehabilitation.*

5. Manuscripts must not exceed 3000 words (exclusive of headings, references, legends for cuts, tables, etc.), and the number of words should be stated on the title page. An original and one carbon copy of the manuscript must be submitted.

6. The essay must not have been published previously.

7. The winner shall receive a cash award of $100.

8. The winner shall be determined by the Awards and Prizes Committee of the American Congress of Physical Medicine and Rehabilitation.

9. All manuscripts will be returned as soon as possible after the name of the winner is announced. The winning manuscript becomes the exclusive property of the American Congress of Physical Medicine and Rehabilitation.

10. The American Congress of Physical Medicine and Rehabilitation reserves the right to make no award if, in the judgment of the Awards and Prizes Committee, no contribution is acceptable. Announcement of the winner will be made at the annual meeting.

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